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Freshwater quality monitoring technical report

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Executive summary

This report assesses spatial and temporal trends in water quality at 51 sites on rivers and streams across the Wellington region over 1997-2003. These assessments are based on monthly physico-chemical and microbiological water quality records, together with annual macroinvertebrate and periphyton monitoring records collected under Greater Wellington Regional Council's Rivers State of the Environment (RSoE) monitoring programme.

Spatial patterns in water quality

Physico-chemical and microbiological water quality in rivers and streams across the region shows a clear spatial pattern related to climate, source of flow, geology and, in particular, land cover. Water quality is highest at RSoE sites located on cool wet, hill-fed river and stream reaches with hard sedimentary geology and unmodified indigenous forest cover. These sites tend to be associated with the Tararua, Rimutaka and Aorangi Ranges and include the Otaki River at Pukehinau, Wainuiomata River at Manuka Track, Hutt River at Te Marua, Waiohine River at the Gorge, and the Ruamahanga River at Mount Bruce. Water quality is generally lower in lowland reaches under indigenous forest cover, and lower again at sites located in pastoral catchments. Water quality is particularly poor at some sites draining dairy catchments, including the lower reaches of the Mangaone Stream, Mangaroa River, Mangatarere Stream and the Whangaehu River. Overall, water quality is poorest at sites draining urban catchments, with the Mazengarb Drain, Ngauranga Stream, and Waiwhetu Stream recording the lowest water quality of the nine urban sites monitored. Significant microbiological contamination is present in all urban streams.

Macroinvertebrate community health exhibits a similar spatial pattern to physico-chemical and microbiological water quality. However, discrepancies between water quality and macroinvertebrate health exist at some RSoE sites, particularly urban sites. These discrepancies suggest that the current RSoE monitoring programme may not be accurately reflecting water quality conditions in some urban streams. Diurnal variation in dissolved oxygen concentrations, pH and water temperature, as well as contamination by stormwater pollutants such as silt, heavy metals and hydrocarbons may be more strongly influencing water quality and the macroinvertebrate communities.

Temporal trends in water quality

Significant temporal trends in water quality were only apparent at a small number of the 51 RSoE sites and were largely confined to lowland rivers or streams influenced by agricultural or municipal wastewater discharges that had ceased during the reporting period. These include the lower reaches of the Waitohu Stream, Mangaone Stream, Ngarara Stream, and the Wainuiomata River. Many of the other trends observed were confined to one or two water quality variables and are difficult to explain, largely because flow-adjusted water quality records were only available for 14 sites (i.e., flow effects can not be ruled out as being a contributing factor to the majority of observed trends). Lower detection limits and standardisation of laboratory analytical methods since August 2003 should help improve future trend reporting.

Regional Policy Statement and Regional Freshwater Plan requirements

The Regional Policy Statement (RPS) and Regional Freshwater Plan (RFP) require a number of reaches on rivers and streams to be managed for specific purposes, including natural state, fishery and fish spawning, and enhancement for aquatic ecosystem health, or fishery and fish spawning purposes. The findings of this report indicate that:

- RSoE sites located on river and stream reaches that are to be managed in their natural state consistently record very good water quality and healthy macroinvertebrate communities.

- Thirteen of the 18 RSoE sites on river and stream reaches that are managed for fisheries have good or very good water quality and macroinvertebrate communities. The other five sites have considerably lower water quality; Kopuaranga Stream at Stewarts, Taueru River at Gladstone, Mangaroa River at Kalcoolies Corner and Te Marua, and the Wainuiomata River at Wainuiomata Golf Course. Of these sites, only the Wainuiomata River showed a significant improvement in water quality over the reporting period.

- Water quality at three of the nine RSoE sites on river and stream reaches in need of enhancement for aquatic ecosystem health purposes showed a significant improvement over the reporting period; the Mangaone Stream at Sims Road Bridge, the Ngarara Stream at Field Way, and Makara Stream at Kennels. Of the remaining sites, two showed a decline in water quality (the lower Mazengarb Drain and Ngauranga Stream), and four showed no change (Makara Stream upstream of Ohariu Stream confluence, Kaiwharawhara Stream at Ngaio Gorge, Waiwhetu Stream at Wainuiomata Hill and Mangatarere Stream at State Highway 2).

- A significant improvement was observed in water quality at all three RSoE sites on the reaches of the Wainuiomata River in need of enhancement for trout fishery habitat and spawning.

Poor physico-chemical and microbiological water quality was identified in several other rivers and streams not specifically mentioned in the RPS or RFP. These include the lower reaches of the Whangaehu River (above its confluence with the Ruamahanga River), the Mangaroa River (Te Marua), and the Waitohu Stream (Norfolk Crescent). The lower reaches of these waterbodies are in dairy catchments and frequently exceed nutrient and microbiological water quality guidelines, although water quality improved significantly in the lower Waitohu Stream over the reporting period.

The Karori Stream at Makara Peak Mountain Bike Park and Porirua Stream at Wall Park are also considered to be in need of enhancement. Both sites recorded very high levels of microbiological contamination. Impacts from urban stormwater and possibly sewer cross-connections are likely to be primarily responsible for this contamination.

A wide range of initiatives are in place to address poor water quality in rivers and streams in the Wellington region. These include riparian rehabilitation projects, the *Take Charge* pollution prevention programme, the *Take Action* environmental education programme, public education campaigns such as *Be the Difference*, and ongoing investigations into contaminated stormwater discharges.

Recommendations

1. Establish a formal quality assurance programme for the collection, processing and storage of all surface water quality information collected under the RSoE programme.

2. Install flow recorders at or near priority RSoE monitoring sites where flow information is lacking, with provision for continuous measurements of key water quality variables such as dissolved oxygen, pH and water temperature during the summer months.

3. Broaden the scope of physico-chemical water quality analytes to include selected stormwater contaminants (e.g., heavy metals) at RSoE sites draining urban catchments and, for a short fixed period at all RSoE sites, major anions and cations.

4. Develop a fish monitoring programme for implementation at selected RSoE monitoring sites.

5. Investigate the development of region-specific water quality guidelines, using long-term water quality records from appropriate reference sites.

6. Identify key surface water quality information of relevance to the RSoE programme collected by resource consent holders and external organisations and collate this for inclusion onto Greater Wellington Regional Council's Water Quality Database.

7. Undertake targeted catchment water quality monitoring to investigate ongoing poor water quality at selected RSoE sites.

8. Review and revise the list of river or stream reaches specified in the RPS and RFP to be managed for enhancement of water quality as appropriate using the findings of this report, together with more recent water quality information collected under the RSoE programme (i.e., post-August 2003).

Contents

1. Introduction

1.1 Background

The Greater Wellington Regional Council (Greater Wellington) manages water quality in rivers and streams of the Wellington region for a variety of values, including natural state, public water supply, recreation and amenity, fish habitat and spawning, and general aquatic ecosystem health. Regular monitoring of physico-chemical and microbiological water quality, together with assessments of instream ecological health, are integral in the management of these values.

River water quality has been routinely monitored in the western half of the Wellington region since 1987 and in the Wairarapa since 1991. Over the years, the two water quality programmes have been reviewed and altered to improve their information value. As a result, there have been a number of changes to the location of monitoring sites, the range of water quality variables monitored, and the methods of water quality analysis. The most significant changes occurred in August 2003 when the two programmes were merged into a single region-wide monitoring programme – the Rivers State of the Environment (RSoE) Monitoring Programme.

Greater Wellington reports annually on the state of the region's rivers and streams based on the results of the RSoE monitoring programme. This report looks at both *state and trends* in water quality over time, focusing on the results of RSoE monitoring over the period 1997 to 2003 inclusive.

1.2 Legislative requirements

Greater Wellington monitors water quality in selected rivers and streams in the Wellington region to fulfil its responsibilities under the Resource Management Act 1991 (RMA). Part IV of the RMA sets out the functions, powers and duties of regional councils. Included in the functions of regional councils are the control of the use of land for the purpose of maintaining and enhancing the quality of freshwater ecosystems, and the control of discharges of contaminants to water (s30(1)). Regional councils also have a duty to monitor and report on the state of the environment to ensure they are effectively carrying out their functions under the RMA (s35(1) and (2)).

Greater Wellington has set out how it will manage freshwater quality in its Regional Policy Statement (1995) and the Regional Freshwater Plan (1999). The relevant objectives and policies in each of these documents are outlined below.

1.2.1 The Regional Policy Statement (RPS)

Chapter 5 (Freshwater):

- Objective 2: the quality of fresh water meets the range of uses and values for which it is required, safeguards its life supporting capacity, and has the potential to meet the reasonably foreseeable needs of future generations.

- Objective 3: Freshwater resources of significance or of high value for cultural, spiritual, scenic, ecosystem, natural, recreational, or other amenity reasons are protected or enhanced.

Method 25 of the freshwater chapter of the RPS seeks an improvement in the water quality of the following water bodies:

- Hulls Creek (Upper Hutt City)
- Makoura Stream (Masterton)
- Mazengarb Drain (Paraparaumu)
- Ngauranga Stream (Wellington City)
- Kaiwharawhara Stream (Wellington City)
- Waikanae River Estuary (Kapiti)
- Wainuiomata River (Hutt City)

1.2.2 The Regional Freshwater Plan (RFP)

The purposes for which various surface water bodies are to be managed in the region are set out in Policies 5.2.1-5.2.5 and 5.2.9 of the RFP:

- Managing water quality in its natural state (Policy 5.2.1)
- Managing water quality in Lake Wairarapa in accordance with the National Water Conservation Order 1989 (Policy 5.2.2)
- Managing water quality for trout fishery and fish spawning (Policy 5.2.3)
- Managing water quality for contact recreation (Policy 5.2.4)
- Managing water quality for public water supply (Policy 5.2.5)
- Managing water quality for aquatic ecosystems (Policy 5.2.6) – the default management purpose for all rivers and streams
- Managing water quality so that it is enhanced to satisfy aquatic ecosystem, contact recreation or trout fishery/ fish spawning purposes (Policy 5.2.9).

Appendix 8 of the RFP sets out the water quality guidelines relevant to each management purpose. These guidelines are based on the standards set in s70, s107 and the Third Schedule of the RMA.

Only rivers and streams with water quality managed for natural state, fish habitat and spawning, aquatic ecosystem health, or enhancement are discussed in detail in this report (Figure 1.1). Rivers and streams managed for contact recreation purposes are reported separately in: *Recreational Water Quality Monitoring Technical Report* (Milne 2005). The water quality of Lake Wairarapa is also reported separately in: *Lake Wairarapa Water Quality Monitoring Technical Report* (Perrie 2005).

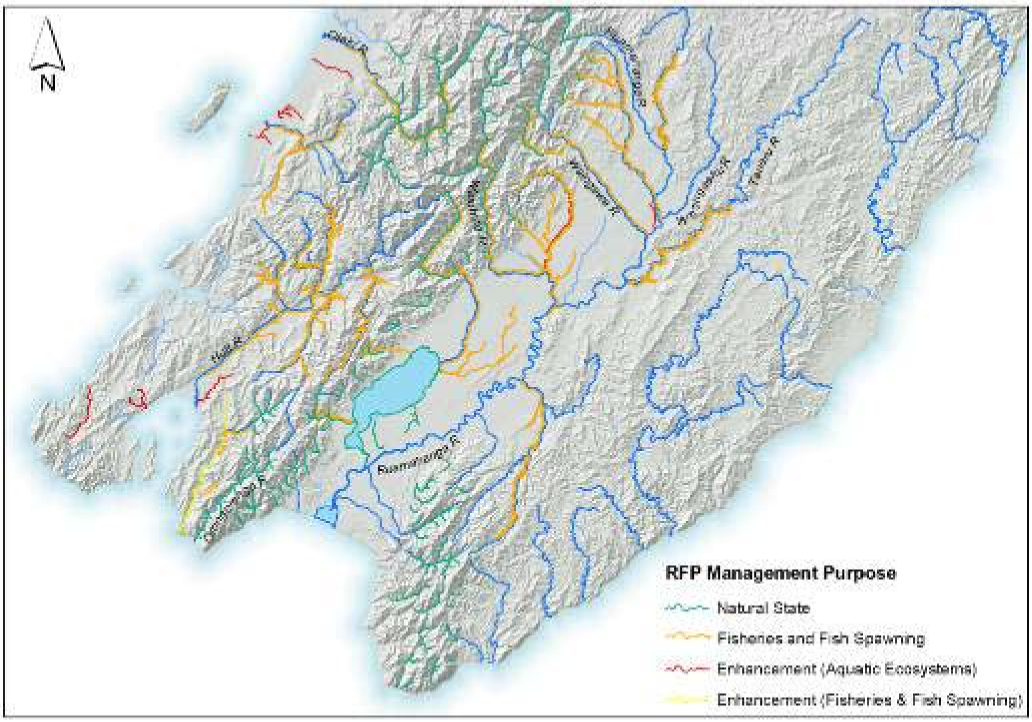

Figure 1.1: River and stream reaches managed for natural state, fisheries or fish spawning, and enhancement, in accordance with the Regional Freshwater Plan.

Note: Policy 5.2.6 of the RFP requires all rivers and streams to be managed for aquatic ecosystem health as a minimum.

1.3 Reporting objectives

The primary aim of this report is to assess the state of water quality in the region's rivers and to identify any significant trends in water quality at selected sites throughout the Wellington region. In particular, the following questions are addressed:

- What is the level of compliance with relevant national water quality guidelines?
- Are there any trends or changes in river water quality in the region, and if so, what are the possible reasons for these trends or changes?

The information contained in this report will be used to assess the effectiveness of management objectives in the RPS and the RFP relating to natural state, fisheries and fish spawning, and enhancement.

The reporting period for state is limited to July 1997 to July 2003 inclusive, for the 51 sites that were part of the RSoE monitoring network over this period. Analyses for trends over time are limited to a similar reporting period, from 1 September 1997 to 31 August 2003 inclusive.

1.4 Report outline

This report has seven sections. The second section provides a brief overview of the RSoE monitoring programme, including the objectives of the programme and changes made to it in recent years. The third section outlines the key pressures on surface water quality in the Wellington region. Sections four and five focus in detail on spatial patterns and temporal trends in water quality respectively. The findings from the trend analyses are discussed in Section 6 in relation to the management objectives of the RPS and RFP. Conclusions and recommendations are presented in Section 7.

2. Overview of surface water quality monitoring programme

2.1 Background

Surface water quality has been routinely monitored in the western half of the Wellington region since 1987 and in the Wairarapa since 1991. Up until a few years ago, this monitoring was effectively conducted under two separate monitoring programmes, with some differences present in the suite of water quality variables and the laboratory analytical methods employed. From around 2000 onwards, greater consistency was achieved between the two programmes and, in 2003, when the key recommendations of a comprehensive review of the surface water quality monitoring in the region were implemented (Warr 2002a), water quality monitoring in the western and eastern parts of the region was merged into a single monitoring programme. At this time, a number of changes were made to the location of monitoring sites, the range of variables monitored and the methods of analysis to improve the representativeness and quality of the information collected.

2.2 Monitoring objectives

The aims of Greater Wellington's Rivers State of the Environment (RSoE) water quality monitoring programme are to:

1. Assist in the detection of spatial and temporal changes in fresh waters.

2. Contribute to our understanding of freshwater biodiversity in the region.

3. Determine the suitability of fresh waters for designated uses.

4. Provide information to assist in targeted investigations where remediation or mitigation of poor water quality is desired.

5. Provide a mechanism to determine the effectiveness of policies and plans.

2.3 Monitoring sites

Routine water quality monitoring sites are illustrated in Figure 2.1. The review of the RSoE monitoring programme by Warr (2002a) led to the deletion of 13 long-term monitoring sites, the relocation of six long-term monitoring sites, and the addition of 18 new long-term monitoring sites. This resulted in a net increase of five sites, from 51 to 56 sites, as of August 2003. The changes made better represent the natural diversity of rivers, streams, major land uses and human activities in the region.

A complete list of historic and current monitoring sites is provided in Appendix 1. This report only discusses water quality at the 51 sites that were monitored up until August 2003 as the data record for the more recent monitoring sites is insufficient for state and trend analysis.

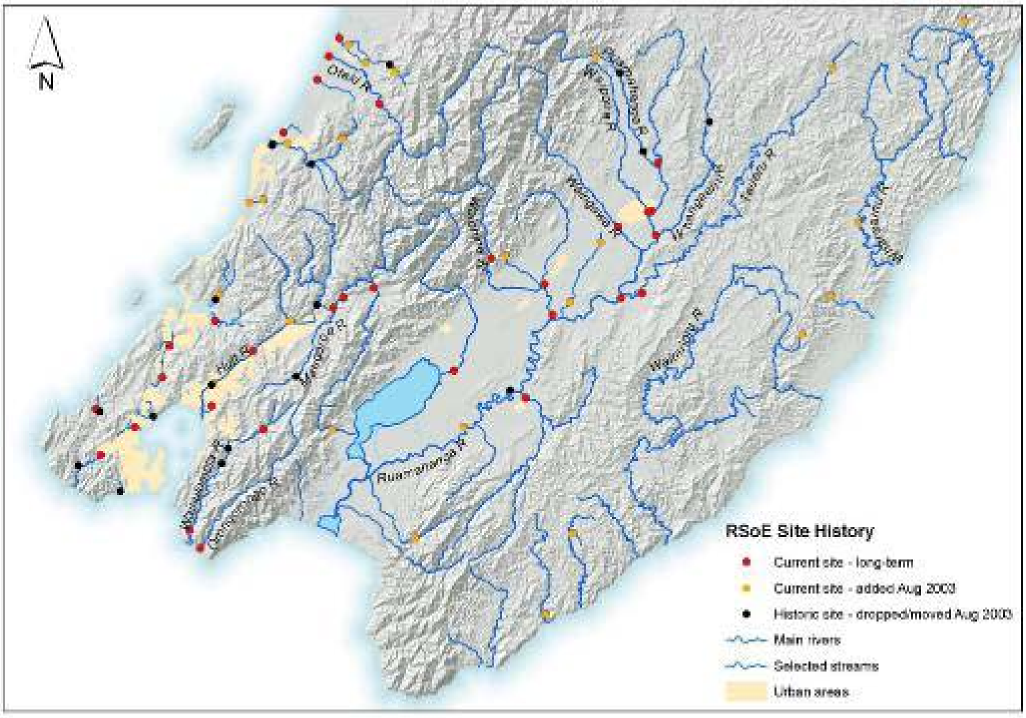

Figure 2.1: Historic and current RSoE monitoring sites.

2.4 Water quality variables

River and stream water quality is assessed at monthly intervals by measuring a range of physico-chemical and microbiological variables, including dissolved oxygen, temperature, pH, conductivity, visual clarity, turbidity, faecal indicator bacteria, total organic carbon, and dissolved and total nutrients. Periphyton cover at each site is also assessed at monthly intervals. The full list of variables, including those introduced following the review of the RSoE monitoring programme by Warr (2002a), is presented in Table 2.1. The rationale for monitoring these variables, together with details of field measurements and analytical methods is provided in Appendix 2.

Table 2.1: Current and historic variables monitored in the RSoE water quality monitoring programme to date.

Variable	Monitoring History
Dissolved Oxygen (both absolute concentration and % saturation)	Regionwide since monitoring began (i.e., since 1987 at sites in western region and since 1991 at sites in Wairarapa).
Temperature	
pH	
Conductivity	
Visual Clarity (Black Disc)	
Turbidity	
Colour	Regionwide since September 2003.
BOD_5	Regionwide since monitoring began up until July 2001.
Total Organic Carbon	Regionwide since July 2001, in place of BOD_5.
Faecal coliforms	Most sites in western region since monitoring began, all sites in Wairarapa from 1994-1997.
Escherichia coli (E. coli)	Sites in western region since September 2003, all sites in Wairarapa since 2000 (with some back to 1994).
Nitrite Nitrogen	All sites in western region since September 2003, most sites in Wairarapa since 1991 (since September 2003 at other sites).
Nitrate Nitrogen	Sites in western region since October/November 1990, all sites in Wairarapa since November 1991.
Ammoniacal Nitrogen	Some sites in western region since 1990 and since 1994 at others, all sites in Wairarapa since monitoring began in 1991.
Total Nitrogen	All sites in western region since July 2001, some sites in Wairarapa since 1991 and since 2001 at others.
Total Kjeldahl Nitrogen	Regionwide since September 2003.
Dissolved Reactive Phosphorus	Sites in western region since October/November 1990, all sites in Wairarapa since November 1991.
Total Phosphorus	All sites in western region since July 2001, some sites in Wairarapa since 1991 and since July 2001 at others.
Periphyton Cover (% cover)	Total % cover at some sites in western region since 1994 and since 2000 at others, all sites in Wairarapa since 1991. Regionwide since September 2003 assessments based on % mats and % filamentous cover.

2.5 Biological monitoring

Water quality in the region's rivers and streams is also assessed through annual biological monitoring, incorporating semi-quantitative assessments of the instream periphyton and macroinvertebrate communities during the summer-autumn period. The record and scope of monitoring differs between sites (Figure 2.2); those sites with substrates comprised of soft sediment have only been monitored since 2003. The assessment of periphyton communities was extended at this time to include quantitative assessments of chlorophyll *a* concentrations and ash free dry weight, and a semi-quantitative assessment of taxonomic richness.

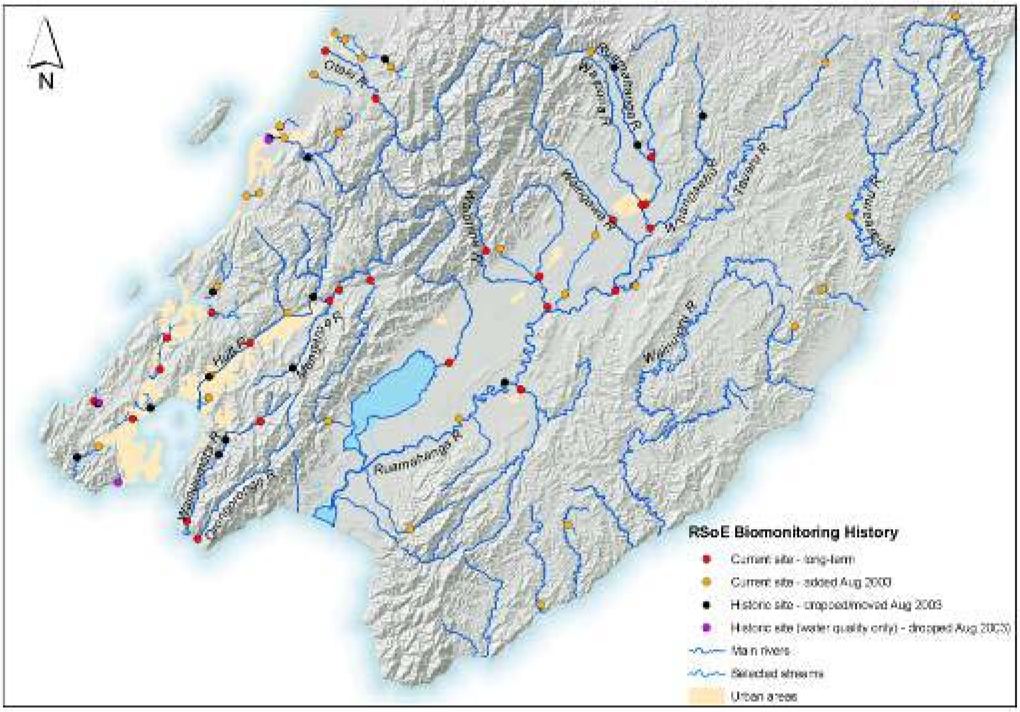

Figure 2.2: Macroinvertebrate monitoring history at RSoE sites.

Details on historic and current biological monitoring methods are provided in Appendix 3. Due to changes in monitoring sites and methods over time, only macroinvertebrate records collected between 1999 and 2003 (or between 1999 and 2004 in some cases) are considered in this report (42 sites).

In the review of the RSoE monitoring programme, Warr (2002a) also recommended that a fish community monitoring programme be developed to provide additional information on ecosystem health and improve our understanding of fish biodiversity in the region. A formal fish monitoring programme has yet to be implemented, although spot electro-fishing was used to assess community composition (species presence/absence) at some RSoE sites in 2004 and 2005. Further monitoring is to be undertaken where resources allow, with the greatest priority given to sites which have few or no fishing records (determined from the NIWA Freshwater Fish Database).

3. Pressures on surface water

Water quality in the region's rivers and streams is affected by a variety of factors including climate, geology, and land-use in the upstream catchment areas. This section provides an overview of the major types of land use in the Wellington region and key pressures on our surface water resources arising from some of these different land uses.

3.1 Land use

A breakdown of major types of land use in the Wellington region is as follows (Figure 3.1):

- Over 26 % of the land area remains under indigenous forest cover and 11.7 % is in scrub. The majority of the forest and scrubland is in the Tararua, Rimutaka, and Aorangi Ranges.
- Agricultural land use (pastoral cover) occupies 47.7 % of the region. Sheep and beef farming is the most widespread form of agricultural land use, covering well over 40 % of the region. It is especially widespread in the northern and eastern Wairarapa. Dairy farming occupies approximately 5 % of the region and is almost entirely limited to the alluvial plains of central Wairarapa and the Kapiti Coast.
- Planted forestry covers 8.3 % of the region and is concentrated around the eastern Wairarapa hill country.
- Urban areas occupy 2.3 % of the region and are concentrated in the south-western part of the region in Wellington City, Hutt City, Upper Hutt City and Porirua City.

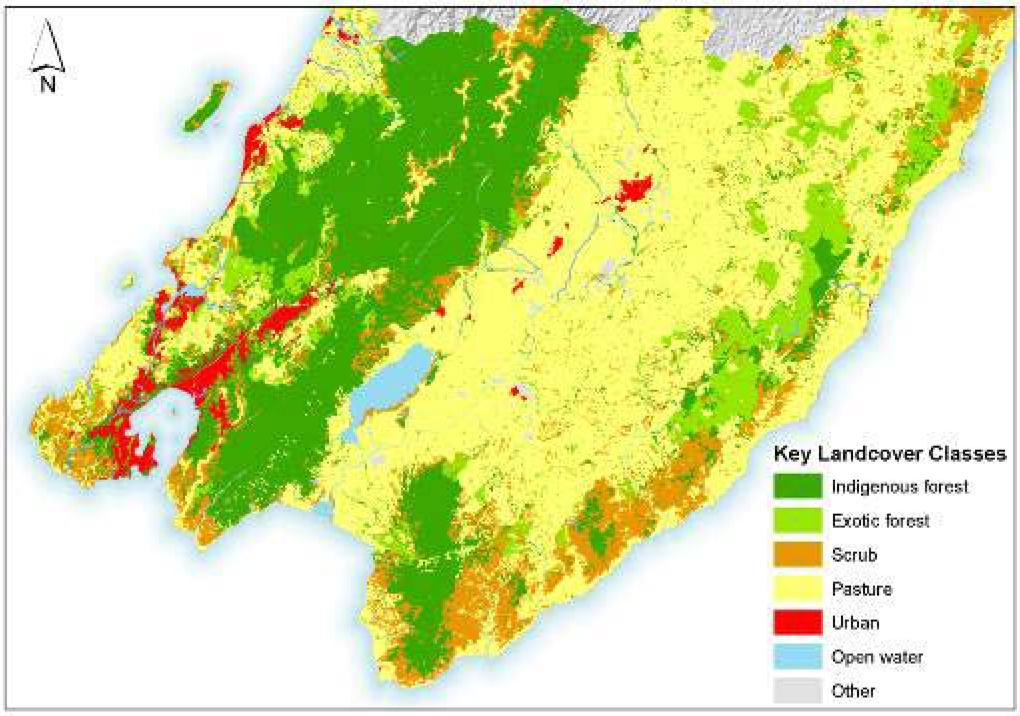

Figure 3.1: Regional land cover (simplified) in the Wellington region.
(Source: Landcover Database, Version 2 - MfE 2001)

Pressures on surface water quality from different land uses within the region range from point source impacts, such as agricultural, municipal and industrial wastewater discharges and stormwater inputs, to diffuse impacts, such as agricultural and urban runoff. In some areas, water abstraction exacerbates these impacts.

3.2 Discharges to fresh water

Major discharges to water in the Wellington region are authorised by resource consents issued under the RMA 1991 and include discharges of agricultural, municipal and industrial wastewater, and discharges associated with landfills, wet weather sewer overflows, river works, water treatment, and earthworks. Major authorised discharges to water as at December 2004 are presented in Figure 3.2. This figure does not include short-term discharges, such as sediment-laden water from earthworks associated with roading and subdivision developments. Stormwater discharges – generally a permitted activity under the RFP - are also widespread in urban areas. Some of these discharges are authorised by resource consents, as they do not meet the permitted activity criteria.

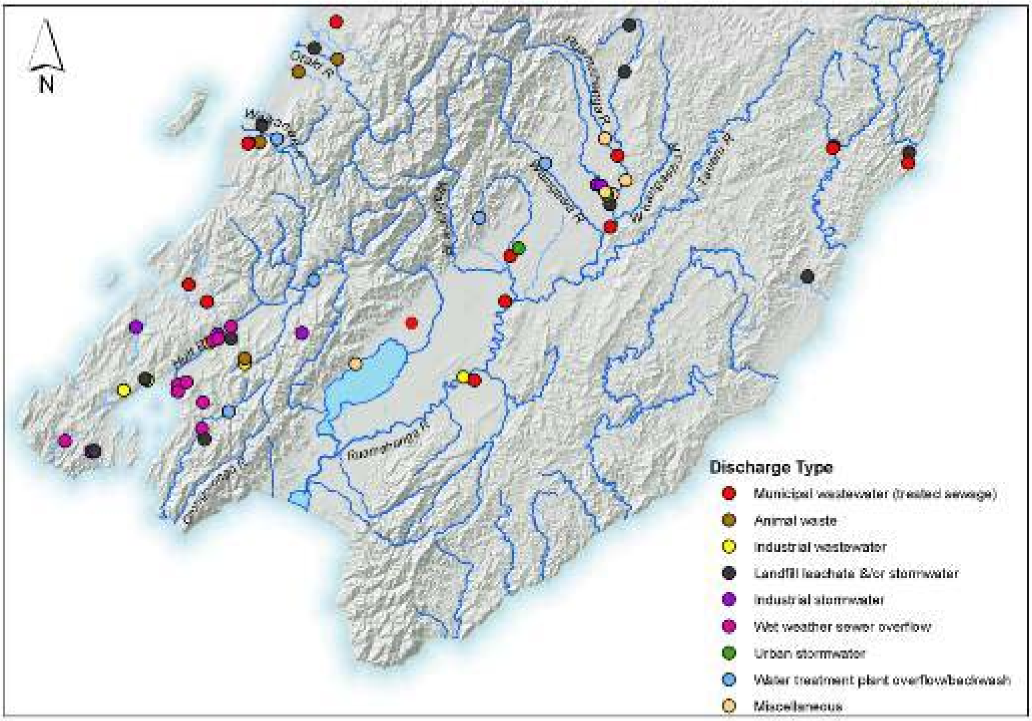

Figure 3.2: Major authorised discharges to surface waters in the Wellington region.

3.2.1 Agricultural wastewater discharges

In 1995, there were 64 authorised agricultural wastewater discharges to water in the Wellington region (Figure 3.3), with all but one of these being dairyshed effluent (Forsyth 2005). Over the last ten years, in recognition of the adverse effects such discharges have on water quality and the useful nutrient load in the effluent as a fertiliser supplement, there has been a major shift to land-based disposal of dairyshed effluent. As a result, only three discharges to water remained in the region in December 2004 (Figure 3.3).

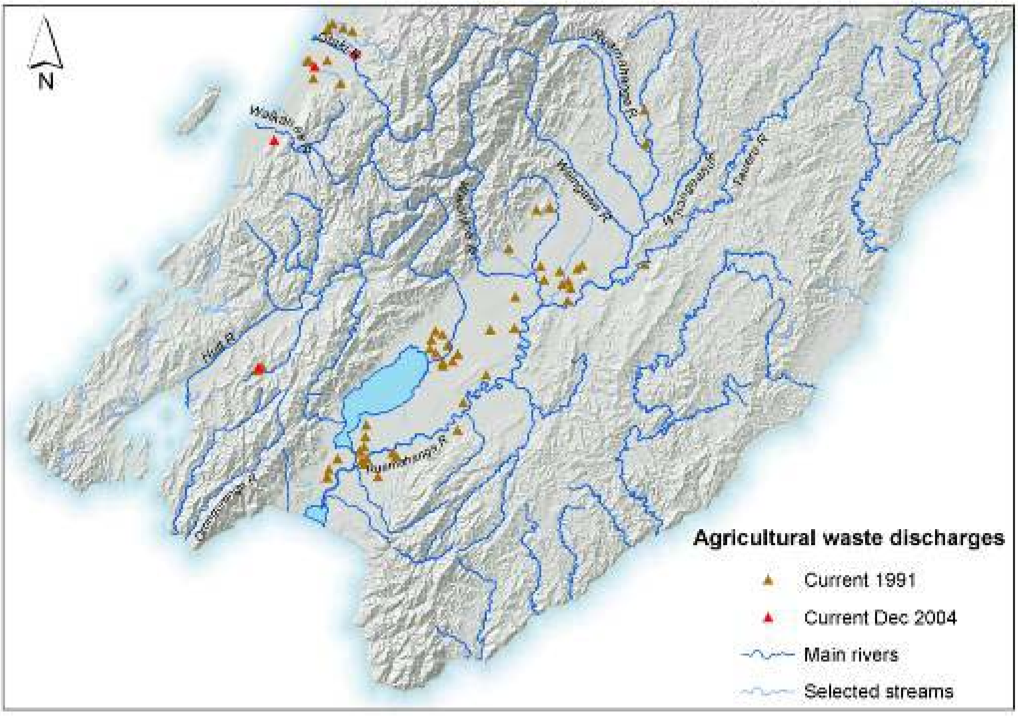

Figure 3.3: Agricultural wastewater discharges to water in the Wellington region in 1991 and 2004.

3.2.2 Municipal wastewater discharges

Treated municipal wastewater (sewage) is discharged directly into rivers and streams from six townships in the Wellington region. As at December 2004, these included all five of the Wairarapa's main townships (Figure 3.4), and

Figure 3.4: Featherston Oxidation Ponds.

Paraparaumu (incorporating sewage from Raumati and Waikanae) on the Kapiti Coast (Table 3.1). Up until late 2001, treated wastewater from Wainuiomata was discharged to the Wainuiomata River and, up until early 2002, treated wastewater from Waikanae was discharged to the Ngarara Stream (via the Black Drain). Wastewater from Wainuiomata is now treated with the rest of Hutt City's wastewater and discharged to the coast at Pencarrow Head.

Table 3.1: Major municipal wastewater discharges to fresh water in the Wellington Region as at December 2004 (adapted from Forsyth 2005).

Township	City/District	Estimated Population Served by the Wastewater Treatment System	Receiving Waterbody
Paraparaumu, Raumati & Waikanae*	Kapiti Coast	30,000	Mazengarb Drain, a tributary of the Waikanae River (*Ngarara Stream, via the Black Drain, up until March 2002)
Masterton	Masterton	17,800	Makoura Stream, a tributary of the Ruamahanga River
Carterton	Carterton	4,500	Mangatarere River up until 2003/2004 when summer land-based treatment disposal has been trialled
Greytown	South Wairarapa	2,000	Papawai Stream, a tributary of the Ruamahanga River
Featherston	South Wairarapa	2,330	Donald's Creek, a tributary of Abbotts Creek and Lake Wairarapa
Martinborough	South Wairarapa	1,500	Ruamahanga River
Other Municipal/Domestic Wastewater Discharges			
Castlepoint	Masterton	1,300	Castlepoint Stream (winter months only when land disposal not possible)
Rathkaele College	Masterton	120 + 235 daytime	Ruamahanga River
Tinui	Masterton	115	Tributary of Putirere Stream
Building Research Assn of NZ	Porirua	100 (daytime)	Tributary of Pauatahanui Stream
Lodge at the Inlet	Porirua	40-60	Tributary of Horokiri Stream
Forest Lakes Camp (G. Crighton)	Kapiti Coast	118-310 (during Oct-Apr)	Lake Waitawa

3.2.3 Industrial wastewater discharges

There are only a small number of industrial wastewater discharges to fresh water in the Wellington region (Figure 3.2). The majority of these are associated with quarries. There are also a few authorised discharges of stormwater from industrial sites in the region, such as quarries, cleanfills and sawmill yards.

3.2.4 Landfill discharges

Figure 3.2 shows the location of authorised landfill discharges (leachate and or stormwater) to surface water in the Wellington region. As at December 2004, there were ten operative landfills in the region, located in Waikanae, Porirua, Wellington (the northern and southern municipal landfills and two private landfills near the suburb of Brooklyn), Wainuiomata, Silverstream (Hutt Valley), Martinborough and Masterton (Figure 3.5). Up until a few months earlier, there was also an operative municipal landfill in Carterton (Forsyth 2005).

Figure 3.5: Masterton Landfill on the true right bank of the Ruamahanga River.

There are 114 known closed landfills in the region (Wellington Regional Council 1998). The majority of these do not have resource consents for leachate and/or stormwater discharges. A desk-top investigation undertaken in 1998 identified 15 as needing further investigation because of effects from leachate (Purchas 1998).

3.2.5 Wet weather sewer overflows

At times sewage can enter the environment before completing its journey through the treatment process. Some examples include:

- Broken or leaky pipes – usually as a result of ageing pipes, construction activities or road works.

- Overflows during rainfall – the wastewater treatment facility may not be able to cope with the volumes of water and sewage entering the facility, and raw or partially treated sewage is discharged directly into the environment. More commonly, during high rainfall, stormwater can enter the sewerage system and cause raw sewage to overflow into the stormwater pipes and, subsequently, directly into surface waters. This currently occurs in a number of areas in Wellington City, Porirua City and Hutt City. Many of these discharges are authorised by resource consents (Figure 3.2).

- Emergency overflows – these can occur periodically during unplanned maintenance of sewerage systems.

3.2.6 River works

A range of riverbed and riverbank works affect water quality, usually for a short time through increased sedimentation and reduced water clarity (Figure 3.6). Sections of the Otaki River, Waikanae River and Hutt River are three rivers subjected to regular disturbance for flood and erosion control purposes. In the Wairarapa, large-scale gravel extraction occurs in parts of the Ruamahanga River (Te Ore Ore and Waingawa River confluence), Waiohine River (at State Highway 2), Waipoua River (above Masterton), Tauherenikau River (State Highway 53) and Huangarua River (above Ponatahi).

Figure 3.6: Turbid water in the Waiohine River at Bicknells as a result of river works upstream.

3.2.7 Water treatment

Several water treatment plants in the Wellington region intermittently discharge waste products to water, typically suspended sediment and aluminium associated with the treatment process (e.g., filter treatment backwash water, overflows, etc). Receiving waters for these discharges include the Waitohu Stream, Waikanae River, Hutt River, Wainuiomata River, Kaipaitangata Stream and the Waingawa River.

3.2.8 Stormwater discharges

In urban areas rainwater collected from roofs, driveways, roads, carparks and other sealed surfaces is piped directly into rivers and streams without treatment. During its travels, this stormwater picks up sediment (Figure 3.7), rubbish and a variety of other contaminants such as heavy metals, hydrocarbons, nutrients and pathogens.

Figure 3.7: Sediment-laden stormwater in urban Wellington. Analysis of complaints made to Greater Wellington Regional Council's Pollution Hotline indicates that a lot of other contaminants enter urban streams via the stormwater system, including paint and detergent.

Although stormwater discharges are generally a permitted activity under the RFP (i.e., no resource consent required), monitoring undertaken by Greater Wellington in recent years has identified that stormwater discharges in some areas may be having more than minor adverse effects on some surface water bodies (e.g., Croucher and Milne 2005, Kingett Mitchell 2005).

3.3 Agricultural/rural runoff and leaching

Agriculture represents the major land-use in the Wellington region, occupying nearly half of the land area. Run-off from agricultural land and other rural areas contributes significantly to nutrient enrichment, microbial contamination and sediment accumulation in nearby waterways. Direct stock access to rivers and streams can add to the degradation through direct deposit of faecal matter into the water and damage to banks (Figure 3.8).

Figure 3.8: Cows in the Otakura Stream in the southern Wairarapa.

Given that virtually all dairyshed effluent in the region is now discharged to land, and the number and size of dairy farms has increased over the last 10 years (Forsyth 2005)[1], the potential for leaching of nutrients into groundwater and surface waters has likely increased in some areas. Based on an estimated figure of over 63,000 dairy cows in the region in 2004, the annual nitrogen load of dairy effluent discharged to land is estimated at 372 tonnes (Forsyth 2005). Most of this effluent is discharged to land in the Wairarapa valley, the Mangaone, Otaki and Waitohu catchments on the Kapiti Coast, and the Mangaora catchment in Upper Hutt.

3.4 Water abstraction

Surface water is abstracted for a variety of uses throughout the region including irrigation, public water supply, water race water supply and industrial uses. Water abstraction places pressure on rivers and streams by reducing the amount of water available for aquatic habitat, physical, chemical and biological processes, recreational activities and other instream uses and values (Figure 3.9). The demand for water is often greatest during dry periods in summer when river and stream flows are at their lowest and temperatures are warm, further exacerbating the pressures placed on these ecosystems.

A number of rivers and streams in the Wairarapa are currently close to, or at full allocation. These include the Kopuaranga River (100 % of core allocation), the Waingawa River (100 %), the Waiohine River (99 %), the upper Ruamahanga River (97 %)[2], and the Waipoua River (88 %), (Watts 2005). In the western part of the region, the core allocation of the Mangaone Stream is at 100 % (Watts 2005).

[1] There were 229 dairy farms in the Wellington region in 2004, compared with 197 in 1995. The average dairy herd size in the region increased from 202 in 1995 to 279 in 2004. The biggest herds (average 318) are in the Masterton and South Wairarapa districts. The number of cows in the region increased from 70,550 in 1998-99 to 74,224 in 2002-03, but decreased over the 2003-04 year to 74,010 (Forsyth 2005).
[2] Defined as the Ruamahanga River from its headwaters to the confluence with the Waiohine River.

Figure 3.9: Low flow in the Waikanae River.

The RFP provides minimum flows for some of the region's rivers to protect instream values from adverse effects associated with abstraction. An assessment of river flow compliance with minimum flows set in the RFP over 1999-2004 undertaken by Watts (2005) found river flows dropped below the minimum requirements every year except 2002 and 2004 in the Waitohu Stream, Wainuiomata River at Leonard Wood Park, Kopuaranga River and Ruamahanga River. The Orongorongo River, Waingawa River and Tauherenikau River also had flows less than minimum during some years. While some of the rivers included in the RFP – including the Mangaone Stream and Otaki, Hutt and Waiohine Rivers – did not fall below their minimum flows during the reporting period, significant low flows did occur, suggesting that the minimum flows are set very low relative to the mean annual low flow (Watts 2005).

4. Spatial patterns in water quality

This section looks at the state of surface water quality at 51 RSoE sites in the Wellington region, to identify any spatial patterns present. A range of physico-chemical and microbiological measurements collected from each site are assessed against national water quality guidelines and median values for selected variables are used to derive a water quality index to compare water quality amongst sites. Macroinvertebrate data collected from annual biological monitoring are also presented and compared amongst sites, together with periphyton data from selected sites. The River Environment Classification (REC) system is used to explain key spatial patterns in water quality.

4.1 Approach to analysis

4.1.1 Water quality data

Data analysis involved both an assessment of compliance[3] with national water quality guidelines and an assessment of spatial variation on a region-wide basis using a water quality index.

(a) Reporting period

Water quality data for each of the 51 RSoE sites monitored over the period July 1997 to July 2003 inclusive were used to assess the state of surface water quality in the Wellington region. More recent data were excluded as significant changes were made to the monitoring site network and the suite of physico-chemical and microbiological variables in September 2003 (refer Sections 2.3-2.4).

(b) Water quality guidelines

The physico-chemical and microbiological water quality variables and guidelines (where applicable) considered in the assessment of water quality state are outlined in Table 4.1. The significance of these variables is discussed in Appendix 2. Most of the guidelines used in this report are the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) "default trigger values" for aquatic ecosystems (herewith denoted as ANZECC 2000). These trigger values are intended to be compared with the *median* value from independent samples at a site. They are not statutory standards and exceedances do not necessarily mean an adverse environmental effect would result. Rather an exceedance is an "early warning" mechanism to alert resource managers to a potential problem or emerging change that may warrant site-specific investigation or remedial action (ANZECC 2000).

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3 The term "compliance" relates more to "comparison with" given that the majority of the water quality guidelines used in this report are trigger values/bench marks and not absolute standards – refer Section 4.1.1(b).

Table 4.1: Physico-chemical and microbiological variables and guideline values.

Variable	Guideline Value	Reference
Water Temperature (ºC)	<20	-
Dissolved Oxygen (% saturation)	≥80	RMA 1991 Third Schedule
pH	6.5-9.0	ANZECC (1992)
Conductivity (uS/cm)	-	-
Visual Clarity (m)	≥1.6	MfE (1994)
Turbidity (NTU)	≤5.6	ANZECC & ARMCANZ (2000)
Total Organic Carbon (mg/L)	-	-
Nitrite-Nitrate Nitrogen (mg/L)	≤0.444	ANZECC & ARMCANZ (2000)
Ammoniacal Nitrogen (mg/L)	≤0.021	ANZECC & ARMCANZ (2000)
Total Nitrogen (mg/L)	≤0.614	ANZECC & ARMCANZ (2000)
Dissolved Reactive Phosphorus (mg/L)	≤0.010	ANZECC & ARMCANZ (2000)
Total Phosphorus (mg/L)	≤0.033	ANZECC & ARMCANZ (2000)
Faecal coliforms (cfu/100 mL)	≤100	ANZECC & ARMCANZ (2000)

The ANZECC (2000) guidelines provide different trigger values for New Zealand upland (>150 m altitude) and lowland ecosystems. While Greater Wellington's RSoE monitoring programme encompasses both upland and lowland sites, for simplicity in comparing water quality between sites, only the lowland trigger values were used in the assessment of compliance with water quality guidelines.

Key points to note in relation to the reported variables and guidelines:

- There are no formal guidelines for temperature, but it is accepted that prolonged water temperatures above 20 ^{o}C are detrimental to some aquatic biota (MfE 2001), including sensitive macroinvertebrate species such as mayflies and stoneflies (Quinn and Hickey 1990). The RFP uses a guideline based on the Third Schedule of the RMA that water temperatures at fresh water sites managed for trout fishery and spawning values should not exceed 25 ^{o}C.

- The dissolved oxygen guideline is the "bottom line" value in the Third Schedule of the RMA 1991; the ANZECC (2000) guidelines (98 to 105% for lowland waters) are considered overly stringent.

- The guideline range for pH is from the ANZECC (1992) water quality guidelines because the range quoted in the 2000 guidelines (pH 7.2 to 7.8 for lowland waters) is considered overly stringent.

- At the time this report was being finalised, it was discovered that the ANZECC (2000) trigger values for visual clarity were based on 20th rather than 80th percentile data from New Zealand rivers[4]. Consequently, the lowland trigger value (0.6 m) was considered inappropriate for assessing water clarity and was replaced with the Ministry for the Environment's (1994) guideline for bathing waters (1.6 m).

[4] The trigger values presented in Table 3.3.11 of the ANZECC (2000) guidelines are not only based on 20th percentile values (ANZECC generally recommends the use of 80th percentile values), but are also printed incorrectly. In the table, trigger values of 0.6 m^{-1} and 0.8 m^{-1} are listed for upland and lowland ecosystems respectively. This is the equivalent of 1.3 m and 1.7 m respectively. According to the author of the clarity guidelines, Rob Davies-Colley (NIWA, pers. comm. 2005), the correct values that should have been published in the guidelines are 0.8 m and 0.6 m for upland and lowland ecosystems respectively.

- Only nitrate nitrogen records were compared against the nitrite-nitrate nitrogen ANZECC default trigger value of 0.444 mg/L as nitrite nitrogen was not monitored at the majority of the RSoE sites during the reporting period. This should not significantly affect compliance assessments; nitrite is rapidly oxidised to nitrate and as a result, concentrations are typically low (Chapman and Kimstach 1998).

- The ammoniacal nitrogen guideline used here relates to aquatic ecosystems (Table 3.3.10, ANZECC 2000) and not ammonia toxicity; toxicity depends on water temperature and pH.

- The faecal coliform guideline relates to livestock drinking water; the data record for *E. coli*, the preferred freshwater microbiological indicator, was insufficient for data analysis.

(c) Water quality index

A water quality "index" incorporating six key physico-chemical and microbiological variables was developed to facilitate inter-site comparisons about the state of water quality in the region's rivers and streams. This approach has been used elsewhere at both a regional level (e.g., Stark and Maxted 2004) and a national level (e.g., Larned et al. 2005).

The water quality index was derived from the *median* values for the following six variables; visual clarity (black disc), dissolved oxygen (% saturation), dissolved reactive phosphorus, ammoniacal nitrogen, nitrate nitrogen and faecal coliform bacteria. Visual clarity was selected as a measure of aesthetic water quality and potential ecological degradation (e.g., light penetration may limit the growth of aquatic plants), while dissolved oxygen is essential for aquatic life. Dissolved reactive phosphorus, ammoniacal nitrogen and nitrate nitrogen were selected as these are all dissolved inorganic nutrients that can affect growth rates of periphyton and macrophytes. Nitrite nitrogen (NO_2-N) is also readily available to periphyton and macrophytes but this form of nitrogen was not monitored until 2003. Future use of the water quality index will include this together with nitrate nitrogen (i.e., NO_x). Faecal coliform bacteria were selected as an indicator of microbiological water quality and are relevant to the use of water for both stock drinking water and contact recreation. As noted in Section 4.2.1(b), the data record for *E. coli*, the preferred freshwater microbiological indicator, was insufficient for inclusion in the water quality index. *E. coli* will be used in future applications of the index.

The application of the water quality index enables water quality at each site to be classified into one of four categories as follows:

- Very good: median values for all six variables comply with guideline values.
- Good: median values for five of the six variables comply with guideline values, of which dissolved oxygen is one variable that must comply.
- Fair: median values for three or four of the six variables comply with guideline values, of which dissolved oxygen is one variable that must comply.

- Poor: median values for less than three of the six variables comply with guideline values.

Sites with a grade of good, fair or poor represent "degraded" sites as the median value of at least one of the six key water quality variables does not comply with guideline values. The degree of degradation is relative, with good sites having the least degraded water quality and poor sites the most degraded water quality.

(d) Data adjustment

During data processing, any water quality variables reported as less than or greater than detection limits were replaced by values one half of the detection limit or the detection limit respectively (e.g. a value of <2 became 1, while a value of >400 became 400).

As outlined in Section 2.1, different laboratories were used for the analysis of water samples from sites in the western Wellington region and sites in the Wairarapa during the reporting period. This resulted in different detection limits for some variables, including dissolved reactive phosphorus, ammoniacal nitrogen, and nitrate nitrogen:

- Dissolved reactive phosphorus: 0.01 mg/L in the western part of the region; 0.003 mg/L in the Wairarapa.
- Ammoniacal nitrogen: 0.05 mg/L in the western part of the region; 0.005 mg/L in the Wairarapa.
- Nitrate nitrogen: 0.03 mg/L in the western part of the region; 0.002 mg/L in the Wairarapa.

In order to ensure that non-detect measurements across all sites were treated equally when deriving the water quality index scores, all non-detect measurements for Wairarapa sites were artificially 'raised' to the higher non-detect concentrations used in the western part of the region. Adjustment was also made in the assessment of compliance with the ANZECC (2000) guidelines for ammoniacal nitrogen; any site with a median concentration at the revised detection limit of 0.025 mg/L was considered to have complied with the ANZECC trigger value of 0.021 mg/L. Similarly, when assessing the number of exceedances of the trigger value for each of the RSoE sites in the western part of the region, any result reported at the detection limit of 0.025 mg/L was taken as complying with the ANZECC trigger value of 0.021 mg/L.

(e) Cautionary notes

- A formal quality assurance (QA) system is not in place for water quality data collected under the RSoE programme. The only changes made to raw data drawn from Greater Wellington's water quality database were the removal of gross outliers, where detected.

- Not all variables were monitored for the full reporting period at all sites, notably total nitrogen, total phosphorus and total organic carbon (refer Table 2.1, Section 2.4). Caution should be exercised when comparing water quality between sites with different periods of record.

- Adjustments to non-detect data to facilitate fair comparisons of water quality between sites in the western Wellington region and sites in the Wairarapa were limited to deriving median values for the water quality index; adjustments were not made to the summary statistics and compliance assessments presented in Section 4.3 as doing so would have “diluted” a significant amount of site-specific water quality information. Therefore care is required when comparing median values between sites in Table 4.5. Caution should also be exercised in comparing water quality between sites in the western Wellington region and sites in the Wairarapa because the different laboratories utilised for the analysis of water samples used different methods for some analyses (refer Appendix 2).

- The manipulation of the dissolved reactive phosphorus and ammoniacal nitrogen non-detect data resulted in some loss of sensitivity of the water quality index at ‘cleaner’ sites which were dominated by non-detect values.

- Compliance with guidelines for dissolved oxygen, temperature and pH is based on a single monthly measurement taken at around the same time on each sampling occasion. These variables can exhibit considerable diurnal fluctuation and may exceed guideline values at other times of the day outside of the sampling period.

- The best reference conditions or guideline values are set by locally appropriate data. The ANZECC (2000) guidelines therefore recommend deriving *site-specific* trigger values for different catchments where possible, using a minimum of two years of water quality results from continuous monthly sampling (24 samples) from appropriate reference sites. The review of the RSoE monitoring programme by Warr (2002a) identified an insufficient number of reference sites in the Wellington region. As a result, changes were made to the site network and consideration could now be given to using site-specific guidelines in future RSoE reporting.

4.1.2 Biological data

Data analysis involved an assessment of compliance with national periphyton cover guidelines and a spatial comparison of macroinvertebrate community health across the Wellington region using four key biological indices.

(a) Reporting period

Periphyton

Reporting of periphyton results is limited to monthly assessments of periphyton cover at selected sites over the period July 1997 to July 2003 inclusive. Detailed annual assessments of periphyton assemblages (taxa richness, abundance, etc.) did not commence until early 2004 (refer Section 2.5).

Macroinvertebrates

The reporting period for macroinvertebrate data (collected annually) is limited to 1999-2003 inclusive for 42 of the 51 RSoE monitoring sites; nine sites with a substrate comprising soft sediment were not sampled for macroinvertebrates during this period. Changes in monitoring sites, sampling methodology, and data archiving prevent a region-wide assessment over a greater length of time, despite the existence of longer monitoring records for some sites.

(b) Guidelines

Periphyton

The New Zealand Periphyton Guidelines (MfE 2000) provide a range of thresholds for periphyton biomass and cover designed to protect various instream values including aesthetics, benthic biodiversity and trout habitat and angling. The threshold considered in this report relates to filamentous periphyton cover in gravel/cobble bed streams managed for trout habitat and angling values. This threshold is that filamentous algae >2 cm long should not exceed 30% coverage of the streambed.

Macroinvertebrates

Macroinvertebrate "guidelines" as an indicator of macroinvertebrate community health and water quality exist in the form of various biotic indices that have been developed over the last 10 to 20 years. These indices are based on the number, type and abundance of macroinvertebrate taxa present at a monitoring site (Table 4.2, Appendix 3).

Table 4.2: Macroinvertebrate indices and grades presented in this report.

Index	Definition	Grades
Macroinvertebrate Community Index (MCI)	An index of sensitivity to organic pollution, based on the presence/ absence of macroinvertebrate taxa (refer Appendix 3).	- Very Good: >120 - Good: 100-120 - Fair: 80-100 - Poor: <80 (Source: Stark 1985, 1993)
Semi-Quantitative MCI (SQMCI)	Similar to the MCI, but also incorporates the relative abundance of the macroinvertebrate taxa present (refer Appendix 3).	- Very Good: >6 - Good: 5-6 - Fair: 4-5 - Poor: <4 (Source: Stark 1998)
% Ephemeroptera, Plecoptera and Trichoptera (EPT) Taxa	The number of pollution-sensitive Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera* (caddisfly) taxa present, expressed as a percentage of total taxa richness. * excludes *Oxyethira* and *Paroxyethira* which are relatively insensitive to pollution	- Very Good: >60 - Moderate: 10-60 - Poor: <10 (Source: Death, unpublished data)
% EPT Individuals	Similar to %EPT taxa but measures the percentage community composition that EPT taxa contribute.	- Very Good: >60 - Moderate: 10-60 - Poor: <10 (Source: Death, unpublished data)

The most widely known index is the Macroinvertebrate Community Index (MCI). MCI values were developed by Stark (1985, 1993, 1998) for assessing organic enrichment of stony or hard-bottomed streams based on sampling macroinvertebrates from riffle (or run) habitats. The MCI relies on prior allocation of scores (between 1 and 10) to freshwater macroinvertebrate taxa (usually genera) based upon their relationship to the degree of organic enrichment. Taxa that are characteristic of un-enriched conditions score more highly than taxa that may be found predominantly in polluted conditions.

(c) Cautionary notes

While periphyton cover has been assessed at all RSoE sites for a number of years, for the majority of sites – including all those in the western region – assessment during the reporting period was limited to *total percentage cover*. Therefore assessment of compliance with the MfE (2000) guidelines for trout habitat and angling values is restricted to a small number of sites where data on *filamentous* algae cover exist.

4.2 The River Environment Classification system – an overview

Rivers and streams within the Wellington region are diverse and some may have differing water quality simply due to their size, climate and underlying geology rather than due to human-induced impacts. To reduce this bias, comparisons between sites are undertaken with the assistance of the River Environment Classification (REC) system. The REC system characterises river environments at six hierarchical levels, corresponding to a controlling environmental factor (Snelder et al. 2003). The factors, in order from the largest spatial scale to the smallest, are climate, source-of-flow, geology, land cover, network position and valley landform. In this report, the first four factors – climate, source-of-flow, geology and land cover – are considered together (Table 4.3, Figure 4.1).

Box and whisker plots (box plots) are used to compare water quality between different REC classes (Figure 4.2). Only a few REC classes were represented by a sufficient number of sites (6-10) to be able to generate meaningful summary statistics for box plots[5]. Therefore, some sites influenced by similar (though not identical) environmental factors were pooled to enable comparisons of water quality at sites across the three main land cover classes represented in the RSoE site network[6]; indigenous forest, pasture and urban (Table 4.4). In some cases, comparisons of water quality were only undertaken across the three major land cover classes.

[5] Box plots were prepared using Sigmaplot 2002. This programme requires a minimum of three data points to generate a median value, six data points to generate 25th and 75th percentile values, and 10 points to generate 5th and 95th percentile values.

[6] Low elevation soft sedimentary sites draining pastoral catchments were not pooled; both climate and stream order was considered too variable among the six sites with these REC characteristics.

Table 4.3: REC classification levels, classes, mapping characteristics, and criteria used to assign river segments to REC classes.

Classification Level and Scale	Classes and Notation	Mapping Characteristics	Class Assignment Criteria
Climate (10^3 – 10^4 km^2)	Warm extremely wet (WX) Warm wet (WW) Warm dry (WD) Cool extremely wet (CX) Cool wet (CW) Cool dry (DC)	Mean annual precipitation, mean annual potential evapotranspiration, mean annual temperature.	*Warm:* mean annual temperature ≥ 12˚C *Cool:* mean annual temperature <12˚C *Extremely wet*: mean annual effective precipitation ≥ 1500 mm *Wet*: mean annual effective precipitation >500 mm and < 1500 mm *Dry:* mean annual effective precipitation ≤ 500 mm
Source of Flow (10^2 – 10^3 km^2)	Mountain (M) Hill (H) Low elevation (L) Lake (Lk)	Catchment rainfall volume in elevation categories, lake influence index.	*M:* >50% annual precipitation volume > 1000 m ASL *H:* 50% precipitation volume 400 to 1000 m ASL *L:* >50% rainfall < 400 m ASL *Lk:* Lake influence index > 0.033
Geology (10 – 10^2 km^2)	Alluvium (Al) Hard sedimentary (HS) Soft sedimentary (SS) Volcanic basic (VB) Volcanic acidic (VA) Plutonic (Pl) Miscellaneous (M)	Proportions of each geological category in section catchment.	Class = spatially dominant geology category unless combined soft sedimentary geological categories exceed 25% of catchment area, in which case class = SS.
Land Cover (10 km^2)	Bare (B) Indigenous forest (IF) Pastoral (P) Tussock (T) Scrub (S) Exotic forest (EF) Wetland (W) Urban (U)	Proportions of each land cover category in section catchment.	Class= spatially dominant land cover category unless pastoral exceeds 25% of catchment area, in which case class = P, or unless urban exceeds 15% of catchment area, in which case class = U.

Source: adapted from Larned et al. (2005).

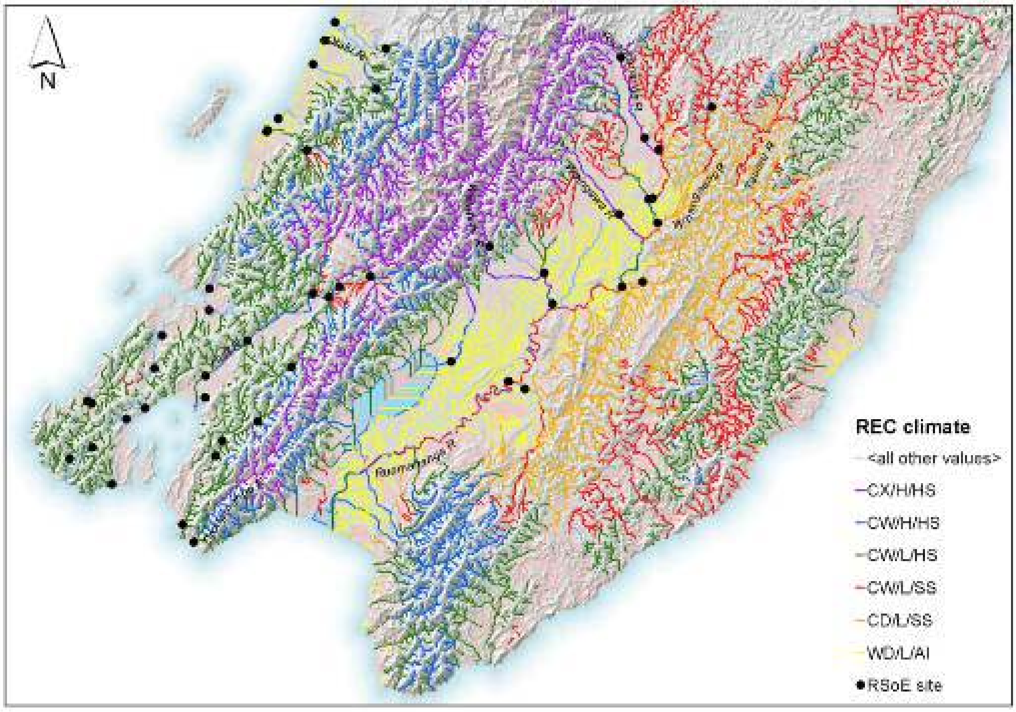


Figure 4.1: Selected REC climate classes and RSoE sites monitored during the period July 1997 to July 2003 inclusive (refer Appendix 1 for full REC classification details for each RSoE site).

Table 4.4: Overview of REC classes used in reporting of (a) physico-chemical and microbiology water quality, and (b) macroinvertebrate community health.

Physico-chemical and microbiological water quality
Four main REC classes incorporating 41 of the 51 RSoE sites: - CX and CW/H/HS/IF (12 sites, 6 CX and 6 CW) - CW/L/HS/IF (8 sites) - CW/L/HS/P (10 sites) - Lowland urban sites (L/U) – all 9 urban sites*, 6 with identical climate (CW) and geology (HS) * Includes one scrub dominated site with 14.3% urban land cover (Site FB18).
Macroinvertebrate community health
Four main REC classes incorporating 33 of the 42 RSoE sites: - CX and CW/H/HS/IF (12 sites, 6 CX and 6 CW) - CW/L/HS/IF (8 sites) - CW/L/HS/P (8 sites) - CW and WW/HS/L/U (5 sites, 4 CW and 1 WW)

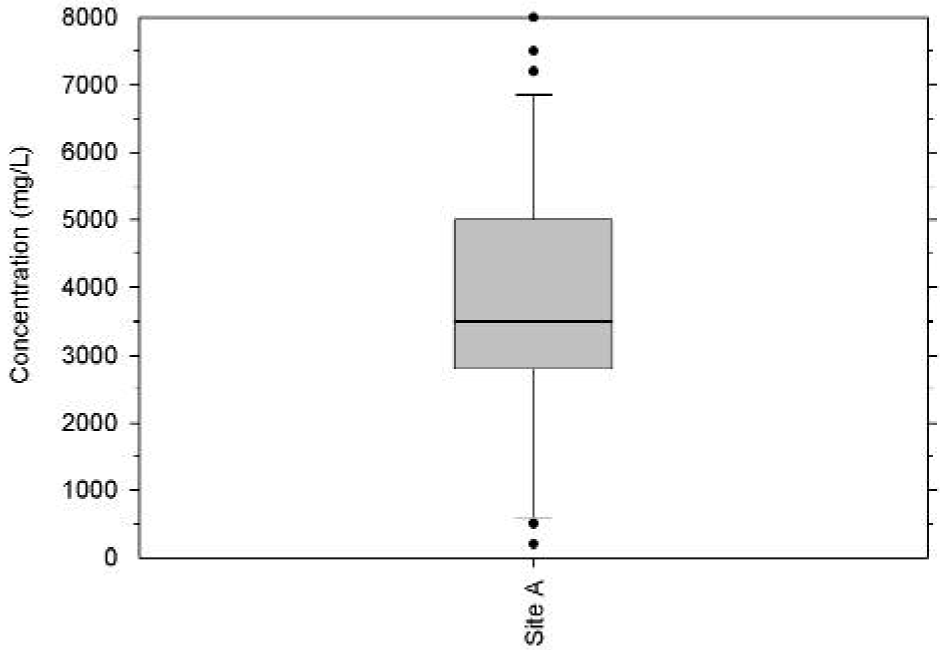


Figure 4.2: Overview of box-plot lay-out;

- the lower and upper boundaries of the box represent the lower (25%) and upper (75%) quartiles of the data respectively
- the horizontal line inside the box represents the median value
- the “whiskers” extending below and above the box represent the 5th and 95th percentile values respectively
- the black dots represent outliers

4.3 Physico-chemical and microbiological water quality results

4.3.1 Water temperature

Water temperature exceeded 20 ˚C at 20 of the 51 RSoE sites on at least one routine sampling occasion during the reporting period (Table 4.5). However, exceedances were rare; only two sites – the Ruamahanga River site at Gladstone and the Tauherenikau River at Websters – exceeded 20 ^{o}C more than 10 % of the time. These are both low elevation sites, and the former drains a predominantly pastoral catchment. Sites in this REC class (i.e., CW/L/HS/P) had a significantly higher median temperature than high elevation and low elevation sites with indigenous forest cover (Figure 4.3). The lowest median temperature was recorded in the Waiohine River at the Gorge (9.2 ^{o}C). At no time did any site record a temperature above the RFP critical threshold of 25 ^{o}C.

4.3.2 Dissolved oxygen

Four low elevation RSoE sites recorded a median dissolved oxygen level below the RMA 1991 critical threshold of 80 % saturation (Table 4.5); the Mangaone Stream at Sims Road Bridge (median 76.2 %), Ngarara Stream at Field Way (38.8 %), Mazengarb Drain upstream of the Waikanae River confluence (63.6 %), and the Waiwhetu Stream at Wainuiomata Hill Bridge (79.1 %). Ngarara Stream at Field Way was the only site below the 80 % threshold on all sampling occasions; the maximum reading at this site was 72.8 %. This site – along with the Mangaone Stream – drains a predominantly pastoral catchment. In contrast, the Mazengarb Drain and Waiwhetu Stream sites drain predominantly urban catchments.

The highest median dissolved oxygen concentrations were recorded at high and low elevation sites with indigenous forest cover (Figure 4.3). Caution should be exercised when comparing *maximum* readings at these and some other sites as many of the readings appear erroneous (e.g., 181 % at Ruamahanga River at Gladstone).

4.3.3 pH

Median pH values at all 51 RSoE sites were within the expected range of pH 6.5 and pH 9. Two sites recorded a pH value below 6.5 and five sites recorded a pH above 9, with three of these sites located in low elevation urban areas; Porirua Stream at Glenside Overhead Cable, Owhiro Stream at mouth and Ngauranga Stream above mouth (Table 4.5).

4.3.4 Visual clarity (black disc)

Four RSoE sites recorded a median visual clarity value below the ANZECC (1994) guideline of 1.6 m (Table 4.5), with four sites falling below the guideline on 100 % of sampling occasions; the Mazengarb Drain upstream of Waikanae River confluence (median 0.36 m), Ngarara Stream at Field Way (0.37 m), Waitohu Stream at Norfolk Crescent (0.47 m), and the Mangaone Stream at Sims Road Bridge (0.52 m). These are all low-elevation sites characterised by soft muddy substrates; some of the sites drain naturally peaty soils, and three of the sites also drain predominantly pastoral catchments. Clarity in the Waiwhetu Stream at Wainuiomata Hill and at the two monitoring sites on the Whangaehu River was also poor; the site at Waihi recorded a median value of 0.65 m while the site further downstream above the confluence with the Ruamahanga River recorded a median of 0.76 m.

Median clarity measurements were greatest at high elevation sites with indigenous forest cover, including the Waikanae River at Reikorangi Bridge (4.06 m), and the Hutt River at Te Marua (3.92 m). The median value for sites in this REC class was well above the MfE (1994) guideline for bathing (1.6 m). The median value for low elevation sites with indigenous forest cover was also above these guidelines. Clarity was noticeably poorer at low elevation sites draining predominantly pastoral catchments (Figures 4.3 and 4.4).

Table 4.5: Summary physico-chemical and microbiological water quality data and compliance with guideline values, for the 51 RSoE sites monitored at monthly intervals over July 1997 to July 2003 inclusive.

Site No.	Site Name	Temperature (ºC)					Dissolved Oxygen (% saturation)					pH					Visual Clarity (m)					Turbidity (NTU)					Conductivity (uS/cm)				Total Organic Carbon (mg/L)			
		Median	Min	Max	*n*	% Results >20 ºC	Median	Min	Max	*n*	% Results <80%	Median	Min	Max	*n*	% Results <6.5 or >9	Median	Min	Max	*n*	% Results <1.6 m	Median	Min	Max	*n*	% Results >5.6 NTU	Median	Min	Max	*n*	Median	Min	Max	*n*
FB01	Waitohu S at Water Supply Intake	11.6	6.7	17.4	72	0	101.6	80.9	119.3	72	0	7.4	7.1	7.8	72	0	3.05	0.16	7.68	69	15.9	0.9	0.3	450	72	6.9	91	57	111	61	1.7	1.2	4.5	25
FB02	Waitohu S at Norfolk Cres	13.5	7.6	19.3	72	0	84.0	41.8	110.9	72	30.6	6.9	6.6	7.2	72	0	0.47	0.06	0.92	71	100	7.9	2.9	250	72	81.9	166	106	235	24	3.4	2.3	6.1	25
FB03	Otaki R at Pukehinau	11.1	6.0	18.1	72	0	101.3	92.3	116.2	72	0	7.4	7.1	8.1	72	0	2.47	0.01	8.58	72	36.1	1.9	0.4	260	72	27.8	67	38	87	61	1.0	0.7	4.1	25
FB04	Otaki R at Mouth	12.5	7.2	21.1	72	1.4	100.8	80.2	123.3	72	0	7.4	7.0	8.5	72	0	2.12	0.02	5.82	72	44.4	2.9	0.5	290	72	36.1	69	41	313	61	1.0	0.6	4.4	25
FB05	Mangaone S at Sims Rd Br	13.0	7.8	19.9	72	0	76.2	36.8	107.9	72	62.5	7.0	6.6	7.4	72	0	0.52	0.10	0.98	72	100	7.1	2.2	58	72	65.3	226	131	365	61	4.0	2.5	10.3	25
FB06	Waikanae R at Reikorangi Br	11.6	5.2	17.5	73	0	102.0	89.5	119.0	73	0	7.4	6.9	8.7	73	0	4.06	0.00	8.00	73	11.0	0.6	0.2	180	73	8.2	96	74	371	62	0.9	0.6	8.8	24
FB07	Ngarara S at Field Way	14.2	7.2	21.4	73	2.7	38.8	5.2	72.8	73	100	7.2	6.4	7.9	73	1.4	0.37	0.12	0.89	73	100	12.0	3.4	48	73	95.9	377	147	942	62	12.1	2.5	29.4	24
FB08	Waikanae R at Oxbow Boat Ramp	13.4	6.6	22.7	73	4.1	89.4	35.7	111.2	73	23.3	7.3	6.8	8.1	73	0	0.88	0.16	3.86	73	82.2	4.4	0.8	39	73	34.2	942	96	43800	62	2.1	1.2	15.3	24
FB09	Mazengarb Drn u/s Waikanae R	14.6	6.4	21.2	73	6.8	63.6	18.7	97.5	73	89.0	7.2	6.7	7.9	73	0	0.36	0.07	1.12	73	100	15.0	4.3	64	73	95.9	524	159	37600	62	9.6	3.6	20.5	24
FB10	Horokiri S at Ongly	12.4	6.0	18.3	73	0	100.6	81.2	123.6	73	0	7.3	6.9	7.7	73	0	2.70	0.07	5.04	73	20.5	1.0	0.2	190	73	9.6	187	157	215	62	1.6	1.2	8.4	25
FB11	Pauatahanui S at Elmwood Br	12.0	5.1	18.5	73	0	95.0	70.1	107.7	73	2.7	7.3	7.0	7.6	73	0	1.94	0.12	4.34	70	37.1	2.7	1.0	55	73	20.5	179	152	483	62	2.8	2.1	8.5	25
FB12	Porirua S at Glenside	12.5	6.6	18.0	73	0	103.8	88.2	141.9	73	0	7.7	7.0	9.2	73	4.1	1.92	0.02	4.90	73	39.7	2.1	0.6	650	73	20.5	266	80	300	62	2.4	2.0	8.8	25
FB13	Porirua S at Wall Pk (Milk Depot)	12.7	6.8	17.9	73	0	104.8	65.9	139.5	73	1.4	7.7	7.1	8.7	73	0	1.75	0.03	3.58	73	38.4	2.9	1.0	550	73	28.8	258	114	300	62	2.3	1.2	5.0	24
FB14	Ohariu S 50m u/s Makara Stream	13.7	2.2	20.5	73	1.4	101.6	81.5	130.1	73	0	7.5	7.0	8.9	73	0	1.14	0.14	2.65	73	69.9	3.6	1.5	42	73	21.9	290	230	391	62	4.5	3.0	10.0	23
FB15	Makara S u/s Ohariu Stream	12.8	3.6	19.1	73	0	99.7	85.7	120.6	73	0	7.4	7.0	7.9	73	0	2.06	0.22	4.68	73	32.9	1.5	0.5	18	73	6.8	250	220	320	62	2.1	1.4	5.3	23
FB16	Makara S at Kennels	13.0	2.5	19.6	73	0	101.1	86.3	117.4	34	0	7.4	7.0	8.7	73	0	1.18	0.12	2.78	73	71.2	4.0	1.6	34	73	31.5	275	233	371	62	3.7	2.2	9.1	24
FB17	Karori S at Makara Peak	12.4	6.7	18.2	73	0	99.6	87.0	118.8	73	0	7.4	7.0	7.9	73	0	2.38	0.12	5.86	72	22.2	1.6	0.8	65	73	15.1	227	54	250	62	1.8	1.2	6.0	24
FB18	Karori S d/s Sth Makara Stream	12.9	4.5	18.8	73	0	101.0	89.5	116.8	73	0	7.6	7.2	8.3	73	0	3.62	0.11	7.48	73	15.1	0.9	0.3	85	73	5.5	228	117	268	62	1.5	1.1	4.5	24
FB19	Owhiro S at Mouth	12.7	7.9	20.0	73	0	101.3	76.9	121.9	73	1.4	8.1	7.2	10.2	73	1.4	1.59	0.09	4.30	72	50.0	2.5	0.7	75	73	32.9	426	228	518	62	2.9	1.9	9.9	25
FB20	Kaiwharawhara S at Ngaio Gorge	12.2	6.2	19.2	73	0	101.6	77.0	119.4	73	1.4	7.8	6.9	8.7	73	0	2.99	0.08	5.40	72	16.7	1.2	0.4	100	73	9.6	289	166	331	62	2.3	1.6	3.9	25
FB21	Ngauranga S 400m u/s Mouth	13.3	8.2	17.9	73	0	100.4	93.1	116.5	73	0	7.9	7.3	9.2	34	2.9	0.94	0.01	2.24	72	90.3	5.9	1.5	160	73	52.1	345	84	400	62	2.1	1.3	4.3	25
FB22	Hutt R at Te Marua Water Intake	10.1	5.1	18.5	73	0	97.9	82.2	111.4	73	0	7.4	6.8	7.7	73	0	3.92	0.22	7.81	73	12.3	0.8	0.2	23	56	13.5	75	50	90	62	2.7	1.2	9.1	25
FB23	Hutt R at Birchville Canoe Club	11.9	5.4	19.2	73	0	102.3	86.5	129.5	73	0	7.4	6.9	8.0	73	0	2.94	0.18	5.79	73	16.4	0.8	0.3	30	73	6.8	86	57	108	62	2.5	1.3	7.5	25
FB24	Hutt R opp. Manor Park G.C.	12.9	6.2	21.1	73	6.8	105.0	84.3	133.8	73	0	7.3	6.9	8.8	73	0	2.44	0.13	5.30	73	26.0	1.5	0.3	50	73	15.1	98	63	114	62	2.3	1.0	7.0	25
FB25	Hutt R u/s of Melling Br	13.2	6.6	21.7	73	5.5	97.5	78.3	116.7	73	2.7	7.3	6.9	8.1	73	0	2.68	0.15	5.80	73	26.0	1.1	0.3	55	73	19.2	97	58	118	62	2.0	1.1	6.3	25
FB26	Pakuratahi R 50m d/s Farm Ck	12.1	5.3	20.0	73	0	98.7	87.3	130.1	73	0	7.1	6.8	7.5	73	0	3.55	0.22	8.06	73	6.8	0.9	0.3	22	72	5.6	87	73	115	62	1.9	1.2	6.5	24
FB27	Mangaroa R at Kalcoolies Cnr	11.2	2.9	19.0	73	0	99.7	83.6	115.1	73	0	7.2	6.7	7.6	73	0	1.55	0.22	3.66	73	50.7	2.7	1.0	24	72	11.1	106	87	144	62	2.9	2.3	6.1	24
FB28	Mangaroa R at Te Marua	12.5	5.1	19.6	73	0	101.6	80.9	124.9	71	0	7.2	6.7	7.8	73	0	1.56	0.16	3.54	73	50.7	1.8	0.7	53	72	5.6	109	92	154	62	3.3	2.2	7.9	24
FB29	Akatarawa R u/s Hutt R confl.	11.4	3.3	19.8	73	0	100.8	85.7	127.6	71	0.0	7.4	6.5	7.6	73	0	3.81	0.34	8.88	73	5.5	0.6	0.2	11	72	1.4	83	64	95	62	1.8	1.0	6.7	24
FB30	Waiwhetu S at Wainui Hill Br	14.1	8.8	20.8	73	2.7	79.1	32.1	143.9	73	53.4	6.9	6.6	7.5	73	0	0.52	0.14	2.44	72	91.7	6.4	1.9	71	73	56.2	244	104	18900	62	2.5	1.3	7.3	25
FB31	Wainuiomata R at Manuka Track	10.3	5.2	15.0	40	0	99.3	89.5	115.8	73	0	7.2	6.8	7.4	40	0	3.34	0.74	6.30	73	2.7	0.8	0.4	8	40	2.5	113	87	125	60	1.5	0.8	4.1	25
FB32	Wainuiomata R at L. Wood Pk	11.6	5.5	19.0	73	0	102.9	74.2	115.6	73	1.4	7.2	6.6	7.7	73	0	2.00	0.26	4.33	73	32.9	1.9	0.6	13	73	8.2	135	107	161	62	1.9	1.3	5.1	25
FB33	Wainuiomata R at Golf Course	12.0	5.9	19.6	73	0	101.6	68.3	121.9	73	1.4	7.3	6.6	7.9	34	0	2.08	0.24	4.03	73	27.4	1.6	0.7	14	73	6.8	146	113	220	62	1.8	1.3	5.3	25
FB34	Wainuiomata R u/s of White Br	12.5	7.0	21.1	71	5.6	97.4	77.5	115.9	71	5.6	7.2	6.7	9.1	71	1.4	1.44	0.16	3.00	71	59.2	2.4	0.7	32	71	19.7	157	122	183	60	1.5	0.9	5.6	25
FB35	Orongorongo R at Orongo. Stn	13.8	7.4	20.1	73	1.4	100.0	56.9	113.0	73	1.4	7.6	7.1	8.6	73	0	2.94	0.02	8.60	73	34.2	1.5	0.4	380	73	26.0	147	94	613	62	1.0	0.7	9.3	25
FB36	Ruamahanga R at Mt Bruce	9.6	4.4	18.4	74	0	101.0	93.0	112.0	74	0	7.3	6.5	7.7	72	0	3.63	0.06	8.99	72	22.2	0.8	0.2	80	74	12.2	56	32	113	72	1.2	0.6	4.5	25
FB37	Ruamahanga R at Dble Bridges	12.0	5.8	20.6	73	1.4	100.1	92.7	127.0	73	0	7.3	6.8	7.7	74	0	2.20	0.08	6.05	73	37.0	1.3	0.3	100	74	14.9	67	36	95	72	1.5	0.6	3.6	25
FB38	Ruamahanga R at Te Ore Ore	13.0	6.8	21.3	73	4.1	101.5	96.2	129.0	74	0	7.7	7.1	8.7	74	0	1.41	0.04	4.76	74	58.1	1.9	0.4	130	74	24.3	125	64	195	74	2.5	0.0	4.5	25
FB39	Ruamahanga R at Gladstone Br	14.2	7.7	23.5	74	12.2	100.2	87.5	181.0	74	0	7.5	6.8	9.4	74	5.4	1.29	0.04	3.54	74	58.1	2.0	0.4	110	74	23.0	108	61	151	74	1.9	0.3	5.3	25
FB40	Ruamahanga R at Waihenga Br	12.4	7.3	22.7	74	4.1	98.4	87.7	125.6	72	0	7.6	6.8	8.3	72	0	1.11	0.03	3.66	74	71.6	2.4	0.5	285	74	23.0	130	82	198	72	2.3	0.3	6.3	24
FB41	Kopuaranga S at Stewarts	12.8	6.5	18.7	72	0	97.0	84.2	133.0	73	0	7.8	6.9	8.4	73	0	1.02	0.04	4.45	72	72.2	2.3	0.5	110	73	20.5	265	97	418	73	4.2	2.0	6.7	24
FB42	Whangaehu R at Waihi	11.8	6.1	18.6	55	0	91.1	58.1	130.1	53	20.8	7.6	7.1	8.6	53	0	0.65	0.00	1.59	55	98.2	4.8	0.6	25	55	38.2	303	215	540	53	7.9	1.0	12.1	24
FB43	Whangaehu R 250 u/s confl.	14.2	6.9	20.5	74	1.4	95.7	61.5	142.0	73	15.1	7.4	6.9	8.1	74	0	0.76	0.03	2.63	74	78.4	3.3	0.6	100	74	39.2	262	136	358	74	5.4	2.1	15.9	24
FB44	Waipoua R at Colombo Rd Br	14.4	7.1	21.8	74	2.7	103.2	97.7	135.4	73	0	7.4	6.8	8.6	74	0	2.29	0.05	5.06	73	31.5	0.7	0.3	45	74	2.7	103	71	195	74	1.7	0.6	6.4	24
FB45	Waingawa R at South Rd	13.4	7.7	24.3	74	8.1	101.1	89.1	114.5	74	0	7.4	6.8	8.3	74	0	2.10	0.06	8.10	74	36.5	1.3	0.3	76	74	9.5	63	45	77	74	1.1	0.0	2.7	25
FB46	Taueru R at Gladstone	14.3	6.1	21.4	74	4.1	104.6	59.1	138.8	73	5.5	8.0	7.2	8.7	74	0	0.95	0.03	3.50	72	75.0	3.2	0.4	390	74	32.4	405	48	545	74	7.2	2.6	14.6	25
FB47	Waiohine R at Gorge	9.2	5.8	18.6	74	0	100.8	97.9	114.5	72	0	7.4	6.8	7.7	74	0	3.53	0.07	8.00	73	17.8	0.8	0.3	38	74	4.1	60	51	68	2	1.1	0.0	7.7	25
FB48	Waiohine R at Bicknells	11.6	6.6	19.7	74	0	98.8	92.4	113.4	72	0	7.1	6.5	7.7	74	0	1.64	0.05	4.13	74	47.3	1.6	0.6	94	74	8.1	76	61	91	2	1.2	0.7	3.0	24
FB49	Mangatarere R at SH2	12.0	7.0	17.9	74	0	95.3	80.1	118.0	72	0	6.9	6.4	7.7	74	1.4	1.58	0.13	3.09	74	52.7	1.3	0.4	33	74	4.1	115	67	162	74	1.8	0.0	3.6	25
FB50	Huangarua R at Ponatahi Br	13.8	6.9	23.9	74	8.1	110.4	96.8	144.6	72	0	8.2	7.6	8.9	74	0	2.48	0.10	7.77	74	33.8	0.7	0.2	36	74	17.6	395	254	510	74	2.9	1.5	7.2	25
FB51	Tauherenikau R at Websters	13.3	7.4	23.5	72	11.1	100.6	88.4	121.5	69	0	7.3	6.7	7.8	73	0	2.13	0.07	6.09	73	38.4	1.3	0.4	80	73	6.8	74	36	94	73	1.3	0.3	4.2	23

Table 4.5 ***cont.***: Summary physico-chemical and microbiological water quality data and compliance with guideline values, for the 51 RSoE sites monitored at monthly intervals over July 1997 to July 2003 inclusive.

Site No.	Site Name	Nitrate Nitrogen (mg/L)					Ammoniacal Nitrogen (mg/L)					Total Nitrogen (mg/L)					Dissolved Reactive Phosphorus (mg/L)					Total Phosphorus (mg/L)					Faecal Coliforms (cfu/100 mL)					
		Median	Min	Max	*n*	% Results >0.444	Median	Min	Max	*n*	% Results >0.025	Median	Min	Max	*n*	% Results >0.614	Median	Min	Max	*n*	% Results >0.010	Median	Min	Max	*n*	% Results >0.033	Median	Min	Max	*n*	% Results >100	% Results >1000
FB01	Waitohu S at Water Supply Intake	0.050	0.010	0.200	72	0	0.025	0.025	0.025	72	0	0.140	0.080	0.490	25	0	0.005	0.005	0.020	72	8.3	0.009	0.005	0.029	25	0	24	1	3,000	72	23.6	1.4
FB02	Waitohu S at Norfolk Cres	0.750	0.150	1.800	72	79.2	0.070	0.025	2.100	72	59.7	0.950	0.440	1.700	25	92.0	0.005	0.005	0.260	72	16.7	0.025	0.009	0.068	25	40.0	505	96	6,000	72	98.6	27.8
FB03	Otaki R at Pukehinau	0.040	0.010	0.400	72	0	0.025	0.025	0.025	72	0	0.090	0.050	0.390	25	0	0.005	0.005	0.010	72	0	0.006	0.005	0.063	25	4.0	6	0.5	3,000	72	2.8	1.4
FB04	Otaki R at Mouth	0.060	0.010	0.230	72	0	0.025	0.025	0.160	72	1.4	0.110	0.050	0.240	25	0	0.005	0.005	0.010	72	0	0.006	0.005	0.029	25	0	66	1	3,000	72	40.3	2.8
FB05	Mangaone S at Sims Rd Br	2.450	0.830	4.700	72	100	0.135	0.025	0.480	72	93.1	2.910	1.170	5.070	25	100	0.005	0.005	0.050	72	16.7	0.034	0.011	0.228	25	52.0	1,115	160	7,500	72	100	54.2
FB06	Waikanae R at Reikorangi Br	0.160	0.030	0.400	73	0	0.025	0.025	0.050	73	1.4	0.230	0.090	0.480	25	0	0.005	0.005	0.030	73	9.6	0.007	0.005	0.059	25	4.0	138	6	3,000	73	67.1	8.2
FB07	Ngarara S at Field Way	0.580	0.020	2.200	73	58.9	1.300	0.025	9.300	73	97.3	2.340	0.154	5.000	25	92.0	0.140	0.010	2.000	73	90.4	0.184	0.067	0.770	25	100	800	40	4,500	73	91.8	41.1
FB08	Waikanae R at Oxbow Boat Ramp	0.345	0.070	2.600	66	34.8	0.025	0.025	1.500	73	43.8	0.540	0.280	3.190	25	44.0	0.010	0.005	1.400	62	22.6	0.078	0.005	2.630	25	64.0	390	60	6,000	73	90.4	23.3
FB09	Mazengarb Drn u/s Waikanae R	1.800	0.070	6.500	69	92.8	0.310	0.025	8.200	73	91.8	4.390	0.890	8.320	25	100	0.100	0.005	4.300	65	93.8	1.280	0.058	5.520	25	100	1,580	100	32,400	73	98.6	65.8
FB10	Horokiri S at Ongly	0.440	0.020	1.400	72	50.0	0.025	0.025	0.025	73	0	0.690	0.120	2.900	25	56.0	0.005	0.005	0.025	72	15.3	0.009	0.005	0.450	25	12.0	410	80	26,200	73	95.9	21.9
FB11	Pauatahanui S at Elmwood Br	0.280	0.010	1.400	72	26.4	0.025	0.025	0.070	73	1.4	0.620	0.170	1.600	25	52.0	0.005	0.005	0.030	72	9.7	0.016	0.005	0.230	25	20.0	680	120	30,000	73	100	32.9
FB12	Porirua S at Glenside	0.945	0.290	2.500	72	87.5	0.025	0.025	0.090	73	5.5	1.250	0.540	2.800	25	88.0	0.005	0.005	0.030	72	30.6	0.017	0.006	0.180	25	16.0	920	240	11,600	73	100	45.2
FB13	Porirua S at Wall Pk (Milk Depot)	0.835	0.180	2.400	72	77.8	0.025	0.025	0.230	73	9.6	1.230	0.370	2.500	25	84.0	0.005	0.005	0.040	72	22.2	0.018	0.005	0.310	25	32.0	1,600	240	15,100	73	100	60.3
FB14	Ohariu S 50m u/s Makara Stream	0.155	0.010	1.800	34	35.3	0.025	0.025	0.080	73	2.7	0.750	0.240	2.020	24	58.3	0.020	0.005	0.140	73	57.5	0.030	0.009	0.126	24	41.7	500	20	9,200	73	95.9	21.9
FB15	Makara S u/s Ohariu Stream	0.280	0.005	1.700	73	38.4	0.025	0.025	0.025	73	0	0.455	0.110	1.300	24	33.3	0.010	0.005	0.030	73	32.9	0.020	0.005	0.042	24	12.5	900	100	5,000	73	98.6	46.6
FB16	Makara S at Kennels	0.310	0.010	1.800	73	45.2	0.025	0.025	0.510	40	1.9	0.700	0.220	1.920	24	62.5	0.010	0.005	0.110	73	42.5	0.038	0.007	0.079	24	58.3	1,000	80	10,200	73	95.9	46.6
FB17	Karori S at Makara Peak	1.400	0.210	2.600	73	98.6	0.025	0.025	0.070	73	2.7	1.495	0.160	2.150	24	95.8	0.020	0.005	0.050	73	68.5	0.037	0.019	0.157	24	54.2	2,140	200	29,100	73	100	80.8
FB18	Karori S d/s Sth Makara Stream	0.880	0.420	1.700	73	98.6	0.025	0.025	0.080	73	11.0	0.985	0.430	1.720	24	91.7	0.030	0.005	0.150	73	98.6	0.037	0.005	0.133	24	58.3	440	20	6,900	73	93.2	15.1
FB19	Owhiro S at Mouth	1.300	0.680	3.400	73	100	0.025	0.025	0.250	73	23.3	1.490	0.820	3.570	25	100	0.005	0.005	0.060	73	27.4	0.019	0.005	0.363	25	32.0	860	100	30,000	73	98.6	42.5
FB20	Kaiwharawhara S at Ngaio Gorge	1.300	0.380	2.500	73	98.6	0.025	0.025	0.170	73	11.0	1.430	0.750	1.970	25	100	0.020	0.005	0.040	73	72.6	0.032	0.006	0.259	25	48.0	540	20	14,500	73	95.9	38.4
FB21	Ngauranga S 400m u/s Mouth	1.900	0.350	3.000	73	97.3	0.050	0.025	0.580	73	52.1	2.180	0.810	2.920	25	100	0.040	0.010	0.360	73	97.3	0.108	0.029	0.655	25	96.0	1,600	200	21,600	73	100	71.2
FB22	Hutt R at Te Marua Water Intake	0.130	0.040	2.400	76	1.3	0.025	0.025	0.025	76	0	0.210	0.140	0.370	25	0	0.005	0.005	0.010	76	0	0.006	0.005	0.036	25	4.0	34	6	300	40	17.5	0
FB23	Hutt R at Birchville Canoe Club	0.210	0.080	0.590	73	1.4	0.025	0.025	0.080	73	5.5	0.380	0.220	0.520	25	0	0.005	0.005	0.140	73	21.9	0.010	0.005	0.399	25	8.0	124	44	1,000	73	67.1	0
FB24	Hutt R opp. Manor Park G.C.	0.300	0.110	0.610	73	16.4	0.025	0.025	0.025	73	0	0.410	0.290	0.660	25	4.0	0.005	0.005	0.020	72	2.8	0.007	0.005	0.046	25	8.0	200	40	2,280	73	75.3	5.5
FB25	Hutt R u/s of Melling Br	0.250	0.070	0.520	73	2.7	0.025	0.025	0.050	73	1.4	0.400	0.250	0.680	25	4.0	0.005	0.005	0.010	73	0.0	0.012	0.005	0.048	25	4.0	110	16	1,300	73	57.5	1.4
FB26	Pakuratahi R 50m d/s Farm Ck	0.370	0.080	0.610	73	28.8	0.025	0.025	0.025	73	0	0.460	0.050	0.810	24	12.5	0.005	0.005	0.020	74	1.4	0.006	0.005	0.032	24	0	92	2	680	73	43.8	0
FB27	Mangaroa R at Kalcoolies Cnr	0.245	0.070	0.850	74	21.6	0.025	0.025	0.180	73	9.6	0.415	0.300	2.180	24	20.8	0.005	0.005	0.020	73	6.8	0.015	0.005	0.251	24	16.7	520	80	4,740	73	94.5	19.2
FB28	Mangaroa R at Te Marua	0.790	0.410	1.800	73	94.5	0.100	0.025	1.500	73	67.1	1.050	0.460	2.300	24	95.8	0.050	0.005	0.400	73	86.3	0.074	0.009	0.463	24	79.2	550	100	7,000	73	98.6	21.9
FB29	Akatarawa R u/s Hutt R confl.	0.080	0.005	0.210	73	0	0.025	0.025	0.050	73	45.2	0.170	0.080	0.320	24	0	0.005	0.005	0.010	73	0	0.005	0.005	0.026	24	0	98	27	1,160	73	49.3	1.4
FB30	Waiwhetu S at Wainui Hill Br	0.580	0.030	1.300	71	66.2	0.100	0.025	0.350	73	78.1	0.900	0.170	1.890	25	88.0	0.005	0.005	0.060	69	14.5	0.035	0.005	0.289	25	52.0	1,500	60	7,100	73	97.3	63.0
FB31	Wainuiomata R at Manuka Track	0.090	0.030	0.210	40	0	0.025	0.025	0.025	73	0	0.170	0.070	0.820	25	4.0	0.005	0.005	0.020	75	8.0	0.011	0.005	0.080	25	8.0	15	0.5	314	71	9.4	0
FB32	Wainuiomata R at L. Wood Pk	0.190	0.010	0.660	73	2.7	0.025	0.025	0.050	73	1.4	0.320	0.110	0.730	25	4.0	0.005	0.005	0.020	73	1.4	0.012	0.005	0.043	25	8.0	470	50	5,700	73	97.3	16.4
FB33	Wainuiomata R at Golf Course	0.620	0.030	4.100	73	71.2	0.090	0.025	0.510	73	63.0	0.340	0.120	2.700	25	28.0	0.130	0.010	1.500	73	75.3	0.016	0.005	0.710	25	28.0	440	30	7,400	73	98.6	17.8
FB34	Wainuiomata R u/s of White Br	0.500	0.030	1.300	71	56.3	0.025	0.025	0.130	71	14.1	0.480	0.190	1.500	25	32.0	0.060	0.010	0.170	71	78.9	0.028	0.005	0.170	25	40.0	200	10	2,990	71	62.0	12.7
FB35	Orongorongo R at Orongo. Stn	0.040	0.005	0.150	73	0	0.025	0.025	0.090	73	4.1	0.090	0.050	0.560	25	0	0.005	0.005	0.010	73	0	0.006	0.005	0.310	25	16.0	27	1	740	73	19.2	0
FB36	Ruamahanga R at Mt Bruce	0.042	0.001	0.317	74	0	0.002	0.003	0.035	74	1.4	0.079	0.040	0.258	25	0	0.005	0.002	0.013	74	2.7	0.007	0.002	0.030	25	0	5	0.5	100	73	0	0
FB37	Ruamahanga R at Dble Bridges	0.098	0.010	0.508	74	5.4	0.002	0.003	0.045	74	2.7	0.150	0.089	0.480	25	0	0.005	0.002	0.011	74	2.7	0.008	0.004	0.036	25	8.0	20	1	404	73	12.3	0
FB38	Ruamahanga R at Te Ore Ore	0.322	0.002	1.092	74	2.7	0.003	0.003	0.045	74	2.7	0.396	0.198	1.500	25	28.0	0.009	0.002	0.092	74	31.1	0.018	0.005	0.190	25	12.0	71	0.5	3,040	74	40.5	2.7
FB39	Ruamahanga R at Gladstone Br	0.403	0.001	1.132	74	45.9	0.012	0.003	0.078	74	24.3	0.503	0.213	1.339	25	28.0	0.026	0.009	0.073	74	98.6	0.038	0.016	0.093	25	68.0	20	0.5	1,520	73	17.8	2.7
FB40	Ruamahanga R at Waihenga Br	0.421	0.001	1.173	74	47.3	0.007	0.003	0.058	74	9.5	0.544	0.213	1.500	25	36.0	0.020	0.004	0.046	74	94.6	0.032	0.021	0.249	25	44.0	50	3	7,400	72	22.2	2.8
FB41	Kopuaranga S at Stewarts	0.957	0.470	2.005	73	98.6	0.013	0.003	0.107	73	16.4	1.251	0.620	2.200	24	100	0.019	0.008	0.083	73	97.3	0.046	0.022	0.472	24	79.2	237	30	11,800	72	87.5	9.7
FB42	Whangaehu R at Waihi	0.051	0.001	0.741	55	5.5	0.015	0.003	0.048	55	16.4	0.552	0.040	1.540	25	36.0	0.029	0.012	0.150	55	100	0.056	0.007	0.291	25	92.0	100	5	1,390	51	49.0	3.9
FB43	Whangaehu R 250 u/s confl.	1.433	0.252	3.197	74	91.9	0.012	0.003	0.154	74	24.3	1.909	0.780	2.697	25	100.0	0.027	0.008	0.354	74	94.6	0.043	0.019	0.478	25	84.0	160	10	9,280	73	72.6	12.3
FB44	Waipoua R at Colombo Rd Br	1.110	0.306	2.473	74	94.6	0.003	0.003	0.019	74	0	1.034	0.428	2.062	25	92.0	0.008	0.003	0.018	74	21.6	0.014	0.005	0.039	25	8.0	36	1	1,120	73	17.8	2.7
FB45	Waingawa R at South Rd	0.079	0.012	0.528	74	2.7	0.003	0.003	0.011	74	0	0.124	0.031	0.690	25	8.0	0.006	0.003	0.013	74	1.4	0.012	0.003	0.028	25	0	9	0.5	488	74	5.4	0
FB46	Taueru R at Gladstone	0.730	0.040	2.551	74	77.0	0.022	0.003	0.084	74	45.9	1.100	0.459	2.300	25	88.0	0.019	0.003	0.068	74	81.1	0.041	0.021	1.109	25	64.0	103	3	41,000	74	50.0	5.4
FB47	Waiohine R at Gorge	0.034	0.001	0.265	74	0	0.003	0.003	0.009	74	0	0.058	0.023	0.490	25	0	0.005	0.003	0.017	74	4.1	0.009	0.003	0.120	25	4.0	2	0.5	80	74	0	0
FB48	Waiohine R at Bicknells	0.367	0.036	1.276	74	41.9	0.011	0.003	0.044	74	12.2	0.476	0.225	1.210	25	36.0	0.021	0.010	0.034	74	97.3	0.028	0.014	0.350	25	24.0	37	5	750	74	13.5	0
FB49	Mangatarere R at SH2	1.668	0.233	3.075	74	97.3	0.079	0.003	0.203	74	89.2	2.037	0.487	3.385	25	96.0	0.078	0.003	0.376	74	98.6	0.102	0.007	0.407	25	96.0	154	5	1,880	74	70.3	4.1
FB50	Huangarua R at Ponatahi Br	0.202	0.003	1.030	74	12.2	0.004	0.003	0.055	74	1.4	0.400	0.056	1.700	25	28.0	0.008	0.002	0.031	74	33.8	0.013	0.004	0.400	25	20.0	43	1	2,170	74	18.9	1.4
FB51	Tauherenikau R at Websters	0.050	0.001	0.294	73	0	0.003	0.003	0.016	73	0	0.093	0.040	0.271	24	0	0.006	0.003	0.018	73	5.5	0.011	0.006	0.040	24	4.2	12	0.5	176	73	6.8	0

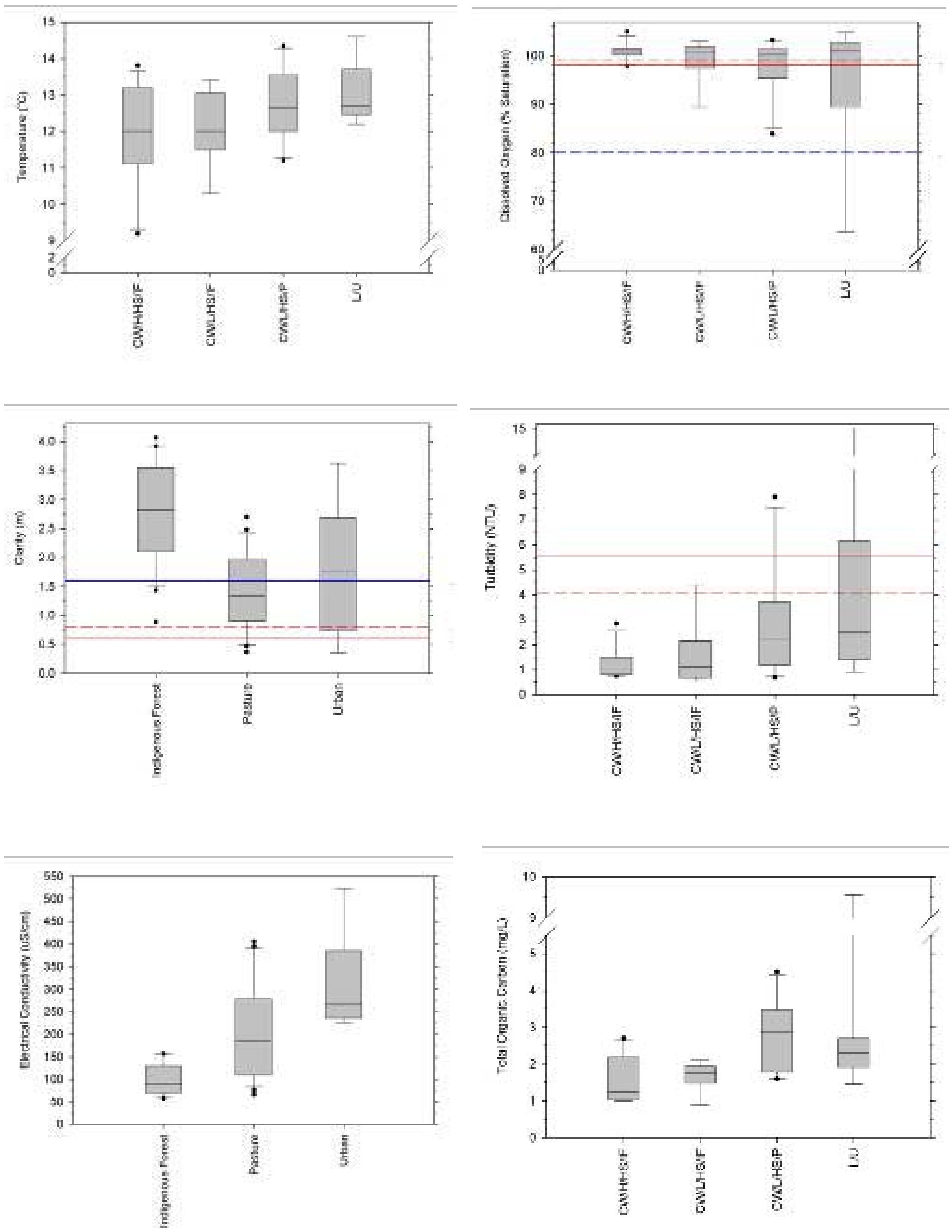


Figure 4.3: Temperature, dissolved oxygen, visual clarity, turbidity, conductivity and total organic carbon box plots for selected REC and/or land cover classes, based on the median values from routine monthly monitoring at RSoE sites over July 1997 to July 2003 inclusive. Note axis breaks on some plots.

- - - - - - - ANZECC (2000) Upland Trigger Value

——— ANZECC (2000) Lowland Trigger Value

- - - - - - - RMA (1991) Third Schedule (minimum standard)

——— MfE (1994) Guideline for Bathing

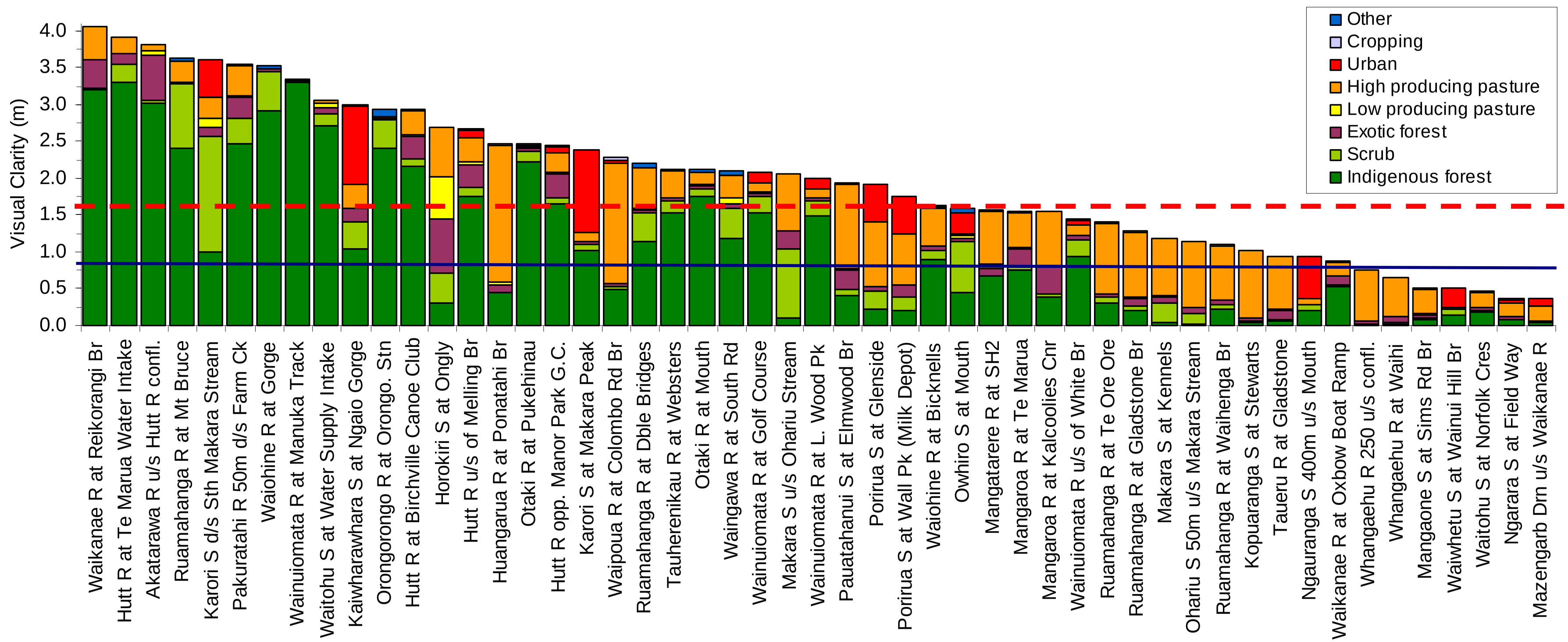


Figure 4.4: RSoE sites ranked from highest to lowest visual clarity (median values from routine monthly monitoring undertaken over July 1997 to July 2003 inclusive), and key land cover classes in the upstream catchment area, as derived from the Landcover Database (MfE 2001).

- - - - - - - MfE (1994) Guideline for Bathing

——— ANZECC (2000) Upland Trigger Value

4.3.5 Turbidity

Median turbidity measurements complied with the ANZECC (2000) trigger value at the majority of RSoE sites over the reporting period. There were five exceptions (Table 4.5), including the four sites that failed to comply with the MfE (1994) clarity guideline on all sampling occasions (Section 4.3.4) and the Ngauranga Stream above the mouth.

Median turbidity measurements were lowest at high and low elevation sites with indigenous forest cover, and lowest in low elevation sites draining predominantly pastoral and urban catchments (Figure 4.3).

4.3.6 Conductivity

Median conductivity concentrations were lowest at sites with indigenous forest cover and highest in sites draining urban catchments (Figure 4.3). On an individual site level, the highest conductivity concentrations were recorded in the Waikanae River at the Oxbow Boat Ramp (median 942 uS/cm). This site is tidally influenced (Warr 2002b) and was removed from the RSoE monitoring programme in 2003.

4.3.7 Total organic carbon

Median total organic carbon concentrations typically ranged from around 1 to 3.5 mg/L (Table 4.5), with the lowest concentrations recorded at high elevation sites with indigenous forest cover. Two low elevation sites affected by municipal wastewater discharges – the Ngarara Stream at Field Way, and the Mazengarb Drain above the Waikanae River confluence – recorded the highest median values (12.1 mg/L and 9.6 mg/L respectively). Overall, median total organic carbon concentrations were highest at low elevation sites in pastoral catchments (Figure 4.3).

4.3.8 Nitrate nitrogen

Median nitrate nitrogen concentrations exceeded the ANZECC (2000) trigger value of 0.444 mg/L at 20 (39 %) of the 51 RSoE sites over the reporting period (Table 4.5). The majority of sites to exceed the trigger value were low elevation sites draining urban catchments (e.g., Karori Stream at both Makara Peak and at the confluence with South Makara Stream, Owhiro Stream at mouth, Kaiwharawhara Stream at Ngaio Gorge, Ngauranga Stream above mouth), sites influenced by upstream municipal wastewater discharges (e.g., Ngarara Stream at Field Way, Mazengarb Drain, Wainuiomata River at both Golf Course and White Bridge, Mangatarere River at State Highway 2), and sites located in dairying catchments (e.g., Kopuaranga Stream at Stewarts, Mangaroa River at Te Marua, Mangatarere River at State Highway 2). The number of exceedances was very high at some sites, with nine sites exceeding the trigger value on 95 % or more of sampling occasions. The majority of these sites are located in Wellington City.

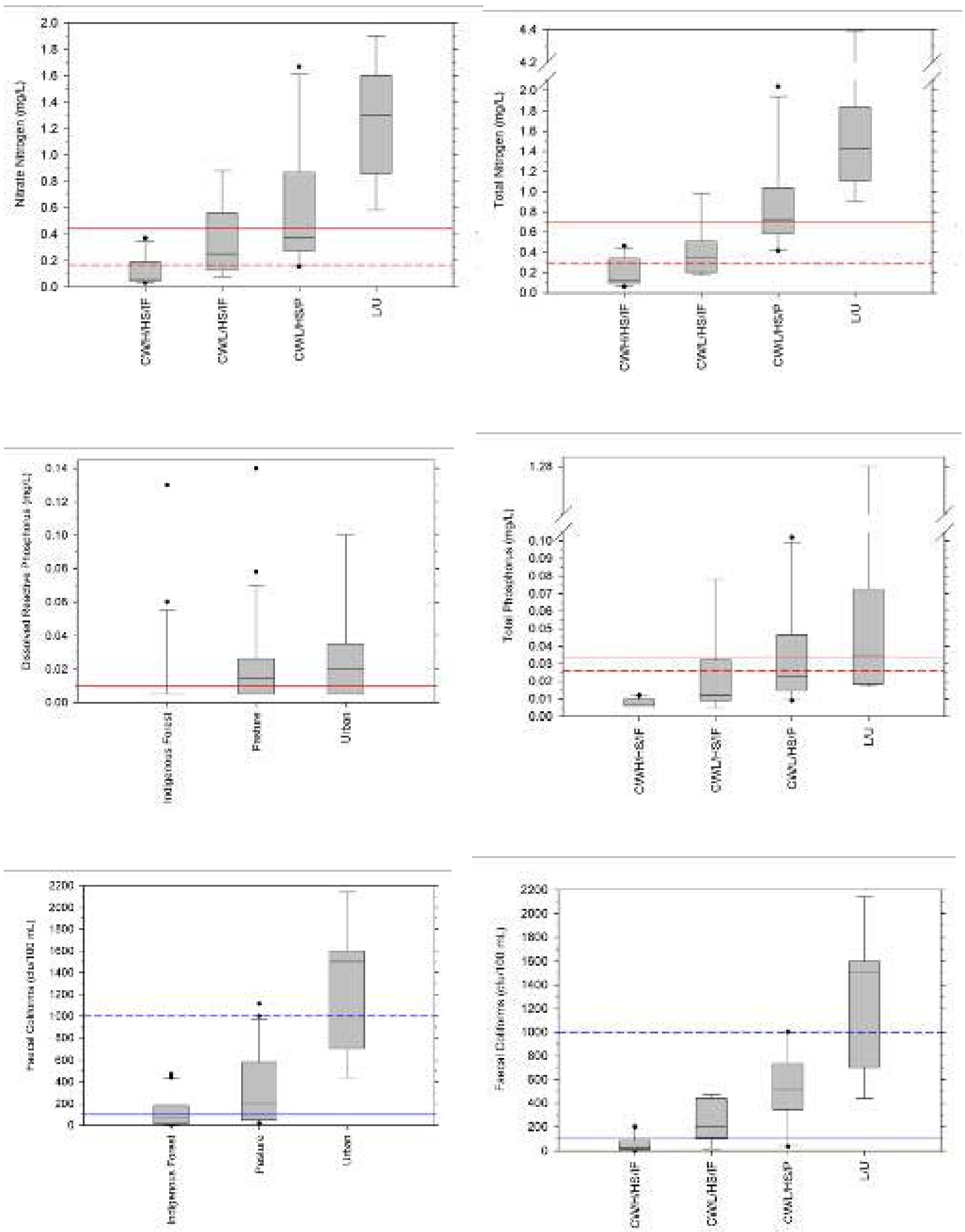


Figure 4.5: Nitrate nitrogen, total nitrogen, dissolved reactive phosphorus, total phosphorus and faecal coliform counts box plots for selected REC and/or land cover classes, based on the median values from routine monthly monitoring over July 1997 to July 2003 inclusive. Note axis breaks on some plots.

- - - - - - - ANZECC (2000) Upland Trigger Value

——— ANZECC (2000) Lowland Trigger Value

——— ANZECC (2000) Stockwater Trigger Value

- - - - - - - - ANZECC (1992) Stockwater Guideline/Secondary Contact Recreation Guideline

On a REC level, median nitrate nitrogen concentrations were lowest at high and low elevation sites with indigenous forest cover, and highest in low elevation sites draining predominantly urban catchments (Figure 4.5).

4.3.9 Ammoniacal nitrogen

Poor detection limits used in the analysis of water samples collected from RSoE sites in the western part of the region prevent a meaningful comparison of median ammoniacal nitrogen concentrations between sites over the reporting period. However, nine low elevation sites clearly recorded median concentrations above the ANZECC (2000) trigger value (Table 4.5), including Ngarara Stream at Field Way (1.30 mg/L), Mazengarb Drain above the Waikanae River confluence (0.310 mg/L), Mangaone Stream at Sims Road Bridge (0.135 mg/L), Mangaroa River at Te Marua (0.10 mg/L), and Waiwhetu Stream at Wainuiomata Hill (0.10 mg/L). Of these sites, three on the Kapiti Coast affected by point source wastewater discharges exceeded the trigger value on more than 90 % of sampling occasions; Ngarara Stream at Field Way (97.3 %), Mangaone Stream at Sims Road Bridge (93.1 %) and the Mazengarb Drain above the Waikanae River confluence (91.8 %). In contrast, 12 sites did not exceed the trigger value on any occasion. The majority of these sites are located on high elevation river or stream reaches under indigenous forest cover (i.e., REC = CW/H/HS/IF).

It is interesting to note that Larned et al. (2005), in analysing trends in water quality in New Zealand rivers over 1996-2002, reported CW/H//HS/IF sites in the Wellington region as having ammoniacal nitrogen concentrations approximately 50 % higher than the national average. It is considered that this is a product of both coarse detection limits and incorrect non-detect values for RSoE sites in the western Wellington region; during preparation of this report, three years of nutrient records for these sites were found to be missing non-detect signs. Greater Wellington's water quality database was corrected prior to data being analysed for this report.

4.3.10 Total nitrogen

Twenty one (43%) of RSoE sites had a median total nitrogen concentration above the ANZECC (2000) trigger value of 0.614 mg/L. The majority of these sites were the same as those listed in Section 4.3.8 as having elevated nitrate nitrogen concentrations. The Mazengarb Drain recorded the highest median concentration (4.39 mg/L) while the Waiohine River at the Gorge recorded the lowest median concentration (0.058 mg/L).

Overall, median total nitrogen concentrations were lower at high and low elevation sites with indigenous forest cover, and higher in low elevation sites draining predominantly pastoral and urban catchments (Figure 4.5).

4.3.11 Dissolved reactive phosphorus

Median dissolved reactive phosphorus concentrations exceeded the ANZECC (2000) trigger value at 18 RSoE sites (Table 4.5). Thirteen of these 18 sites also exceeded the ANZECC (2000) trigger value for nitrate nitrogen. All 18 sites drain either pastoral or urban catchments (Figure 4.5), with the exception of the Wainuiomata River at both Golf Course and White Bridge. For the majority of the reporting period, municipal wastewater was discharged into the Wainuiomata River upstream of these sites.

The number of exceedances was very high at some sites, with nine sites exceeding on 95% or more of sampling occasions. The majority of these sites were in pastoral catchments. One site – the Whangaehu River at Waihi – exceeded the trigger level on 100% of sampling occasions.

4.3.12 Total phosphorus

Fifteen (31%) of RSoE sites had a median total phosphorus concentration above the ANZECC (2000) trigger value of 0.033 mg/L. Thirteen of these sites also recorded a median dissolved reactive phosphorus concentration above the ANZECC (2000) trigger level and all sites drain either pastoral or urban catchments (Figure 4.5). Two sites – the Ngarara Stream at Field Way and Mazengarb Drain above Waikanae River confluence – exceeded the trigger level on 100% of sampling occasions.

On a REC level, median total phosphorus concentrations were lowest at high and low elevation sites with indigenous forest cover, and highest in low elevation sites draining predominantly urban catchments (Figure 4.5).

4.3.13 Faecal coliforms

Median faecal coliform counts exceeded the ANZECC (2000) stockwater trigger value of 100 cfu/mL at 31 (61%) of the 51 RSoE sites, with 19 of these sites exceeding the trigger value on 95% or more of sampling occasions (Table 4.5). Only two sites – the Ruamahanga River at Mount Bruce and Waiohine River at Gorge – did not exceed the trigger level on any sampling occasion.

If the former stockwater and secondary contact recreation guideline of 1,000 cfu/100 mL (ANZECC 1992) is considered, the median faecal coliform count at six (12%) of the 51 sites monitored over 1997-2003 exceeded this; the Mangaone Stream at Sims Road Bridge, Mazengarb Drain above the Waikanae River confluence, Porirua Stream at Wall Park, Karori Stream at Makara Peak, Ngauranga Stream above mouth and Waiwhetu Stream at Wainuiomata Hill (Table 4.5). All six of these sites are located in lowland areas and five drain urban catchments. The Karori Stream at Makara Peak recorded the greatest number of exceedances; more than 80% of sample results exceeded 1,000 cfu/100 mL with the highest count being 29,100 cfu/100 mL.

Faecal coliform counts were strongly influenced by catchment land cover, with the lowest median counts recorded at sites with indigenous forest cover, and the highest counts at sites draining urban catchments (Figure 4.5). Elevation also had some influence; median counts were lower at high elevation than lower elevation forest sites.

4.3.14 Water quality index

Application of the water quality index (WQI) resulted in the following overall water quality grades for the 51 RSoE sites monitored in the Wellington region over the 1997-2003 reporting period (Figure 4.6):

- Very good: 14 sites (27.5 %)
- Good: 11 sites (21.6 %)
- Fair: 14 sites (27.5 %)
- Poor: 12 sites (23.5 %)

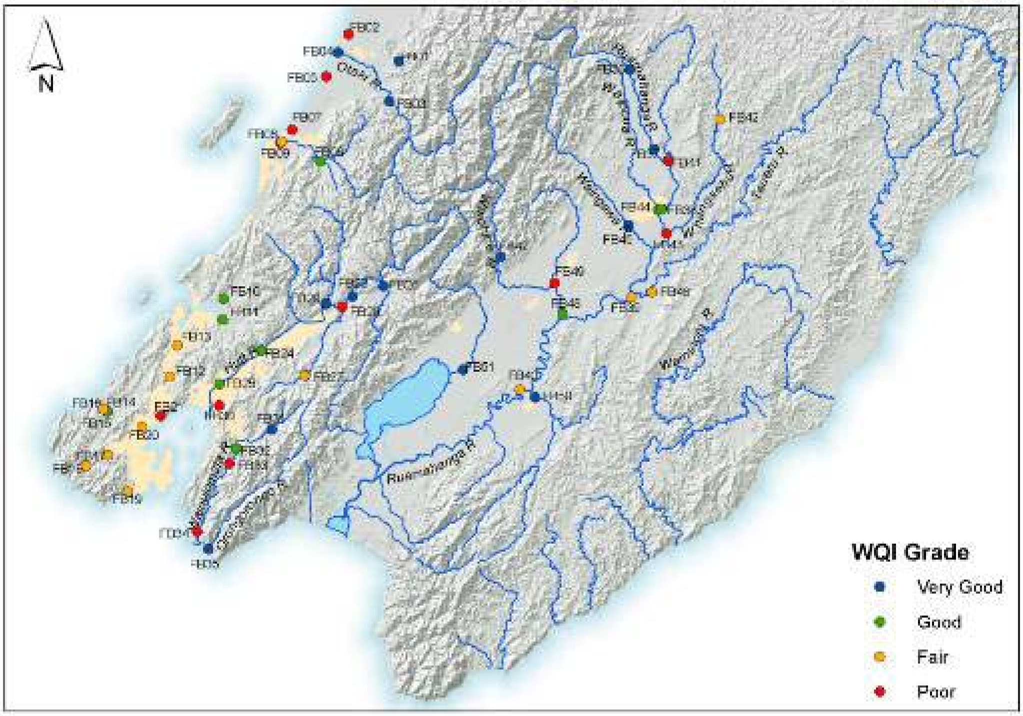


Figure 4.6: Water Quality Index grades for RSoE sites monitored at monthly intervals over July 1997 to July 2003 inclusive, based on compliance of median dissolved oxygen, visual clarity, nitrate nitrogen, ammoniacal nitrogen, dissolved reactive phosphorus and faecal coliform values with guideline values.

As outlined in Section 4.1.1(c), the WQI is for comparative purposes rather than an absolute measure of water quality; sites with a grade of good, fair or poor are all considered degraded because the *median* value of at least one of the six physico-chemical or microbiological variables in the WQI exceeded a guideline value (Table 4.6). In addition, as the WQI is based on median values (i.e., 50 % compliance), sites awarded the same water quality grade may exhibit varying degrees of compliance (from 51 to 100 %) with the guideline value. Therefore to differentiate between "better" and "poorer" sites within a water quality grade, in Table 4.6 the sites have been ranked based on the number of guideline exceedances for each of the six key variables.

Table 4.6: Water Quality Index grades for RSoE sites monitored at monthly intervals over July 1997 to July 2003 inclusive, based on compliance with guideline values.

Rank	Site No.	Site Name	Guideline Compliance (Median Values)						REC
			DO	Clarity	FC	NO_3-N	Amm. N	DRP	
Very Good Water Quality									
1	FB47	Waiohine R at Gorge	✓	✓	✓	✓	✓	✓	CX/H/HS/IF
2	FB03	Otaki R at Pukehinau	✓	✓	✓	✓	✓	✓	CW/H/HS/IF
3	FB36	Ruamahanga R at Mt Bruce	✓	✓	✓	✓	✓	✓	CX/H/HS/IF
4	FB22	Hutt R at Te Marua Water Intake	✓	✓	✓	✓	✓	✓	CX/H/HS/IF
5	FB01	Waitohu S at Water Supply Intake	✓	✓	✓	✓	✓	✓	CW/H/HS/IF
6	FB35	Orongorongo R at Orongo. Stn	✓	✓	✓	✓	✓	✓	CW/H/HS/IF
7	FB31	Wainuiomata R at Manuka Track	✓	✓	✓	✓	✓	✓	CW/L/HS/IF
8	FB04	Otaki R at Mouth	✓	✓	✓	✓	✓	✓	CW/H/HS/IF
9	FB51	Tauherenikau R at Websters	✓	✓	✓	✓	✓	✓	CW/H/HS/IF
10	FB45	Waingawa R at South Rd	✓	✓	✓	✓	✓	✓	CX/H/HS/IF
11	FB26	Pakuratahi R 50m d/s Farm Ck	✓	✓	✓	✓	✓	✓	CX/H/HS/IF
12	FB37	Ruamahanga R at Dble Bridges	✓	✓	✓	✓	✓	✓	CX/H/HS/P
13	FB29	Akatarawa R u/s Hutt R confl.	✓	✓	✓	✓	✓	✓	CW/L/HS/IF
14	FB50	Huangarua R at Ponatahi Br	✓	✓	✓	✓	✓	✓	CD/L/SS/P
Good Water Quality									
15	FB06	Waikanae R at Reikorangi Br	✓	✓	×	✓	✓	✓	CW/L/HS/IF
16	FB25	Hutt R u/s of Melling Br	✓	✓	×	✓	✓	✓	CW/L/HS/IF
17	FB24	Hutt R opp. Manor Park G.C.	✓	✓	×	✓	✓	✓	CW/H/HS/IF
18	FB32	Wainuiomata R at L. Wood Pk	✓	✓	×	✓	✓	✓	CW/L/HS/IF
19	FB23	Hutt R at Birchville Canoe Club	✓	✓	×	✓	✓	✓	CW/H/HS/IF
20	FB10	Horokiri S at Ongly	✓	✓	×	✓	✓	✓	CW/L/HS/P
21	FB44	Waipoua R at Colombo Rd Br	✓	✓	✓	×	✓	✓	CW/L/HS/P
22	FB11	Pauatahanui S at Elmwood Br	✓	✓	×	✓	✓	✓	CW/L/HS/P
23	FB38	Ruamahanga R at Te Ore Ore	✓	×	✓	✓	✓	✓	CW/L/SS/P
24	FB15	Makara S u/s Ohariu Stream	✓	✓	×	✓	✓	✓	CW/L/HS/P
25	FB48	Waiohine R at Bicknells	✓	✓	✓	✓	✓	×	CW/H/HS/P
Fair Water Quality									
26	FB27	Mangaroa R at Kalcoolies Cnr	✓	×	×	✓	✓	✓	CW/L/HS/P
27	FB39	Ruamahanga R at Gladstone Br	✓	×	✓	✓	✓	×	CW/L/SS/P
28	FB40	Ruamahanga R at Waihenga Br	✓	×	✓	✓	✓	×	CW/L/SS/P
29	FB16	Makara S at Kennels	✓	×	×	✓	✓	✓	CW/L/HS/P
30	FB12	Porirua S at Glenside	✓	✓	×	×	✓	✓	CW/L/HS/U
31	FB13	Porirua S at Wall Pk	✓	✓	×	×	✓	✓	WW/L/HS/U
32	FB42	Whangaehu R at Waihi	✓	×	✓	✓	✓	×	CW/L/SS/P
33	FB08	Waikanae R at Oxbow Boat Ramp	✓	×	×	✓	✓	✓	CW/L/HS/IF
34	FB14	Ohariu S 50m u/s Makara Stream	✓	×	×	✓	✓	×	CW/L/HS/P
35	FB18	Karori S d/s Sth Makara Stream	✓	✓	×	×	✓	×	CW/L/HS/U
36	FB20	Kaiwharawhara S at Ngaio Gorge	✓	✓	×	×	✓	×	CW/L/HS/U
37	FB17	Karori S at Makara Peak	✓	✓	×	×	✓	×	CW/L/HS/U
38	FB46	Taueru R at Gladstone	✓	×	×	×	✓	✓	CD/L/SS/P
39	FB19	Owhiro S at Mouth	✓	×	×	×	✓	✓	CW/L/HS/U
Poor Water Quality									
40	FB34	Wainuiomata R u/s of White Br	✓	×	×	×	✓	×	CW/L/HS/IF
41	FB41	Kopuaranga S at Stewarts	✓	×	×	×	✓	×	CW/L/SS/P
42	FB33	Wainuiomata R at Golf Course	✓	✓	×	×	×	×	CW/L/HS/IF
43	FB43	Whangaehu R 250 u/s confl.	✓	×	×	×	✓	×	CD/L/SS/P
44	FB02	Waitohu S at Norfolk Cres	✓	×	×	×	×	✓	CW/L/HS/P
45	FB05	Mangaone S at Sims Rd Br	×	×	×	✓	×	✓	WW/L/AL/P
46	FB49	Mangatarere R at SH2	✓	✓	×	×	×	×	CW/L/HS/P
47	FB28	Mangaroa R at Te Marua	✓	✓	×	×	×	×	CW/L/HS/P
48	FB21	Ngauranga S 400m u/s Mouth	✓	✓	×	×	×	×	CW/L/HS/U
49	FB30	Waiwhetu S at Wainui Hill Br	×	×	×	×	×	✓	WW/L/HS/U
50	FB07	Ngarara S at Field Way	×	×	×	×	×	×	WW/L/AL/P
51	FB09	Mazengarb Drn u/s Waikanae R	×	×	×	×	×	×	WD/L/M/U

Sites with very good water quality

Twelve of the 14 sites with "very good" water quality are located on cool wet, high elevation (11 sites) or low elevation (1 site) river and stream reaches associated with the Tararua, Rimutaka and Aorangi Ranges (Table 4.6). As a result, all have their upstream catchments in unmodified indigenous forest cover and share similar geology (hard sedimentary). The remaining two sites also drain catchments with approximately 20-50 % indigenous forest cover but fall into the pasture land cover class under the REC system as they have more than 25 % land cover in high producing pasture; the Huangarua River at Ponatahi Bridge and the Ruamahanga River at Double Bridges.

The Waiohine River at the Gorge had the highest water quality of the 15 sites (Figure 4.7), achieving close to 100 % compliance with guideline values over July 1997 to July 2003. Exceedances of guidelines were limited to clarity (two occasions) and dissolved reactive phosphorus (one occasion).

Figure 4.7: Waiohine River at Gorge.

Sites with good water quality

Eleven sites were assigned a grade of "good" under the WQI, indicating that median values of five of the six water quality variables in the WQI complied with guideline values (Table 4.6). The majority of the "good" sites were located in low elevation reaches and had upstream catchments predominantly in indigenous forest cover (5 sites) or pasture cover (6 sites). Eight of the sites had a median faecal coliform count that failed to meet the ANZECC (2000) stockwater trigger value of 100 cfu/100 mL, with four of these exceeding the trigger value on 95 % or more of sampling occasions.

Median faecal coliform counts in the Waipoua River at Colombo Road, the Waiohine River at Bicknells, and the Ruamahanga River at Te Ore Ore complied with the ANZECC (2000) stockwater trigger value. These sites exceeded either a nutrient guideline (Waipoua River and Waiohine River) or the MfE (1994) guideline for visual clarity (Ruamahanga River).

The Waikanae River at Reikorangi Bridge had the highest water quality of the 11 sites. Although this site exceeded the faecal coliform trigger value on 67 % of sampling occasions, it complied with dissolved oxygen, visual clarity, dissolved nutrients guidelines on at least 90 % of sampling occasions. In contrast, the Waiohine River at Bicknells had the lowest compliance with guideline values. This site exceeded visual clarity, nitrate nitrogen, and dissolved reactive phosphorus guidelines on 47 %, 42 %, and 97 % of sampling occasions respectively.

Sites with fair water quality

Fourteen sites were assigned a grade of "fair", because median values of only three or four of the six water quality variables in the WQI complied with guideline values (Table 4.6). With the exception of the Waikanae River at Oxbow Boat Ramp, all 14 sites were low elevation sites draining predominantly urban (6 sites) or pastoral catchments (7 sites). The water quality variables that exceeded guidelines were faecal coliforms (11 sites), visual clarity (9 sites), nitrate nitrogen (7 sites) and dissolved reactive phosphorus (7 sites).

The Mangaroa River at Kalcoolies Corner had the highest water quality of the 14 "fair" sites. This site, along with seven other sites, complied with four of the six water quality variables. In contrast, six sites – including both sites on Karori Stream, only complied with three of the six water quality variables. The Owhiro Stream at Mouth had the lowest compliance with guideline values. This site is located in urban Wellington and exceeded visual clarity, nitrate nitrogen, and faecal coliform guideline values on 50 %, 100 %, and 99 % of sampling occasions respectively.

Sites with poor water quality

Twelve RSoE sites received a grade of "poor", indicating that median values of less than three water quality variables in the WQI complied with guideline values (Table 4.6). Median values at two sites – Ngarara Stream at Field Way and the Mazengarb Drain above the Waikanae River confluence – failed to comply with all guideline values.

The majority of the sites graded with poor water quality are located on lowland river and stream reaches draining catchments with pasture cover (7 sites) or urban activity (3 sites). The two exceptions are sites on the Wainuiomata River upstream of White Bridge and at the Wainuiomata Golf Course; these sites have their upstream catchment predominantly in indigenous forest cover. However water quality at these sites was, up until late 2001, affected by the discharge of municipal wastewater from the Wainuiomata WWTP. Leachate from the Wainuiomata Landfill may also have impacted on the lower site during part of the reporting period. Three other sites were also affected by a direct point source municipal wastewater discharge; the Ngarara Stream at Field Way (Waikanae WWTP up until March 2002), the Mazengarb Drain

(Paraparaumu WWTP) (Figure 4.8), and the Mangatarere River at State Highway 2 (Carterton WWTP). Water quality at the latter site was probably also influenced by discharges of dairyshed effluent during part of the reporting period. The largest piggery in the region is also located in this catchment. Rural and/or urban runoff also impacts on most sites, with bird life likely to be another factor contributing to poor water quality in the Ngarara Stream (e.g., Nga Manu Sanctuary) and the Mazengarb Drain (e.g., Ratanui Lakes and Lake Mazengarb).

Dairy farm activity is likely to be the primary contributor to poor water quality in the lower Whangaehu River, the Mangaone Stream at Sims Road Bridge and the Waitohu Stream at Norfolk Crescent. Poor water quality in the Mangaroa River at Te Marua is also attributed largely to dairy farming, as well as a large piggery which discharged wastewater to a tributary of the river during the reporting period. Some septic tank seepage may also be present higher in the catchment. Water quality in the Waiwhetu Stream is affected by several sources, including stormwater and discharges of diluted raw sewage as a result of sewer overflows during extreme rainfall events. Resource consent monitoring records for authorised overflows indicate that such discharges typically occur up to half a dozen times a year at up to three different locations (Hutt City Council 2005).

Figure 4.8: Mazengarb Drain at Mazengarb Reserve.

4.4 Biological monitoring results

4.4.1 Periphyton

RSoE sites in the Wairarapa were monitored monthly for filamentous periphyton cover over July 1997 to July 2003 inclusive. All but one site – the Waingawa River at South Road – exceeded the MfE (2000) threshold of 30% cover on at least one monitoring occasion (Table 4.7, Figure 4.9). Most nuisance periphyton growth occurred in late summer, coinciding with low and relatively stable river flows and warmer water temperatures (Figure 4.10). A similar finding was reported by Milne (2005) for freshwater recreational sites on the Ruamahanga, Waingawa, Waipoua and lower Waiohine Rivers.

Table 4.7: Summary of compliance with the MfE (2001) guideline for filamentous periphyton cover over July 1997-July 2003 inclusive.

Site No.	Site Name	Total No. of Sampling Occasions	% Occasions >30% Filamentous Periphyton Cover
FB36	Ruamahanga R at Mt Bruce	42	2.4
FB37	Ruamahanga R at Dble Bridges	72	2.8
FB38	Ruamahanga R at Te Ore Ore	70	7.1
FB39	Ruamahanga R at Gladstone Br	70	5.7
FB40	Ruamahanga R at Waihenga Br	70	2.9
FB41	Kopuaranga S at Stewarts	70	35.7
FB42	Whangaehu R at Waihi	42	2.4
FB43	Whangaehu R 250 u/s confl.	71	5.6
FB44	Waipoua R at Colombo Rd Br	71	7.0
FB45	Waingawa R at South Rd	70	0
FB46	Taueru R at Gladstone	69	17.4
FB47	Waiohine R at Gorge	72	2.8
FB48	Waiohine R at Bicknells	72	1.4
FB49	Mangatarere R at SH2	72	5.6
FB50	Huangarua R at Ponatahi Br	72	30.6
FB51	Tauherenikau R at Websters	71	5.6

Figure 4.9: Prolific growth of periphyton and macrophytes in the Whangaehu River.

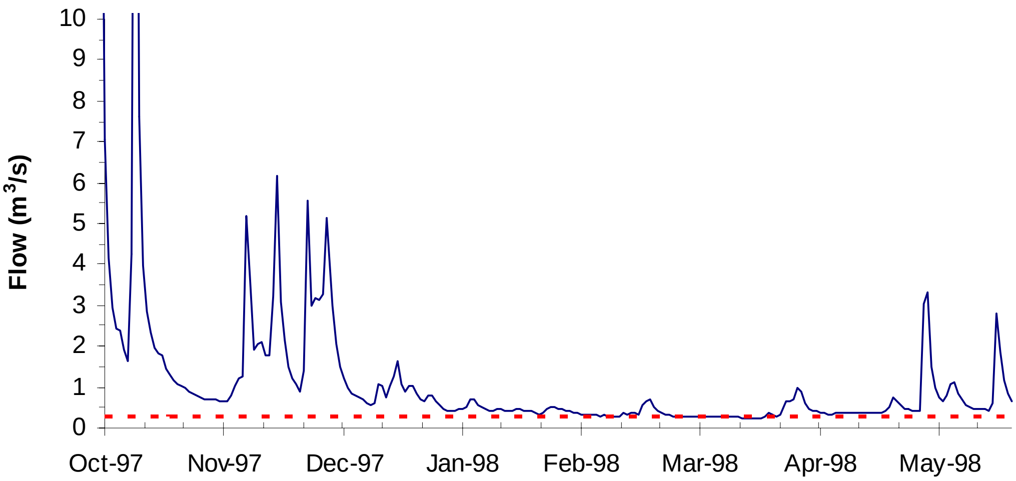


Figure 4.10: Mean daily flows in the Kopuaranga Stream at Palmers Bridge over 1 October 1997 to 31 May 1998 inclusive. The red broken line indicates the RFP minimum flow for this site.

Three RSoE sites exceeded the guidelines more than the other sites; Kopuaranga Stream at Stewarts (35.7 % of sampling occasions), Huangarua River at Ponatahi Bridge (30.6 %), and Taueru River at Gladstone (17.4 %). These sites share almost identical REC climate (cool dry (2 sites) or cool wet), source of flow (low elevation), geology (soft sedimentary) and land cover (pastoral) classifications. Moreover, all three sites are affected by low base-flows (Watts 2005). The effect of low base flows on periphyton growth in the Kopuaranga Stream is exacerbated by significant upstream water abstraction (refer Section 3.4) and very high dissolved nutrient concentrations (refer Table 4.5). Taueru River flows are also affected by upstream water abstraction (Watts, pers. comm. 2005).

4.4.2 Macroinvertebrates

Mean scores for four macroinvertebrate community health indices, based on annual sampling over 1999-2003 inclusive, are presented in Table 4.8. Index scores for individual sampling years are provided in Appendix 4.

Table 4.8: Mean values for four macroinvertebrate indices for 42 of the 51 RSoE sites sampled annually over 1999-2003 inclusive.

Site No.	Site Name	MCI		SQMCI		% EPT (Taxa)		% EPT (animals)	
FB01	Waitohu S at Water Supply Intake	137.1	V. Good	7.49	V. Good	64.4	V. Good	80.7	V. Good
FB03	Otaki R at Pukehinau	130.1	V. Good	7.12	V. Good	59.3	Moderate	75.3	V. Good
FB04	Otaki R at Mouth	106.7	Good	5.67	Good	33.9	Moderate	49.5	Moderate
FB06	Waikanae R at Reikorangi Br	136.0	V. Good	7.18	V. Good	58.4	Moderate	61.2	V. Good
FB08	Waikanae R at Oxbow Boat Ramp	100.3	Good	4.97	Fair	21.3	Moderate	17.0	Moderate
FB10	Horokiri S at Ongly	90.6	Fair	3.57	Poor	33.8	Moderate	9.96	Poor
FB11	Pauatahanui S at Elmwood Br	80.4	Fair	3.31	Poor	14.2	Moderate	0.91	Poor
FB12	Porirua S at Glenside	82.9	Fair	2.77	Poor	15.0	Moderate	3.84	Poor
FB13	Porirua S at Wall Pk	75.3	Poor	2.63	Poor	9.54	Poor	1.82	Poor
FB14	Ohariu S 50m u/s Makara Stream	88.2	Fair	3.96	Poor	29.4	Moderate	18.2	Moderate
FB16	Makara S at Kennels	90.3	Fair	4.31	Fair	31.5	Moderate	19.4	Moderate
FB18	Karori S d/s Sth Makara Stream	105.4	Good	5.97	Good	44.3	Moderate	37.8	Moderate
FB19	Owhiro S at Mouth	69.0	Poor	2.48	Poor	7.52	Poor	2.33	Poor
FB20	Kaiwharawhara S at Ngaio Gorge	81.9	Fair	3.44	Poor	17.4	Moderate	23.4	Moderate
FB21	Ngauranga S 400m u/s Mouth	59.0	Poor	2.15	Poor	5.25	Poor	1.20	Poor
FB22	Hutt R at Te Marua Water Intake	132.6	V. Good	7.25	V. Good	62.3	V. Good	77.1	V. Good
FB23	Hutt R at Birchville Canoe Club	125.7	V. Good	7.19	V. Good	55.2	Moderate	77.4	V. Good
FB24	Hutt R opp. Manor Park G.C.	109.7	Good	5.45	Good	46.0	Moderate	52.8	Moderate
FB25	Hutt R u/s of Melling Br	103.8	Good	5.29	Good	39.1	Moderate	43.3	Moderate
FB26	Pakuratahi R 50m d/s Farm Ck	130.6	V. Good	7.09	V. Good	56.0	Moderate	65.2	V. Good
FB27	Mangaroa R at Kalcoolies Cnr	93.6	Fair	3.62	Poor	28.1	Moderate	10.6	Moderate
FB28	Mangaroa R at Te Marua	98.9	Fair	4.29	Fair	35.8	Moderate	24.8	Moderate
FB29	Akatarawa R u/s Hutt R confl.	133.4	V. Good	7.07	V. Good	61.3	V. Good	78.7	V. Good
FB31	Wainuiomata R at Manuka Track	142.4	V. Good	7.35	V. Good	64.7	V. Good	72.5	V. Good
FB32	Wainuiomata R at L. Wood Pk	87.8	Fair	3.09	Poor	22.8	Moderate	12.5	Moderate
FB33	Wainuiomata R at Golf Course	78.5	Poor	3.08	Poor	19.9	Moderate	13.4	Moderate
FB34	Wainuiomata R u/s of White Br	76.5	Poor	3.43	Poor	18.5	Moderate	24.1	Moderate
FB35	Orongorongo R at Orongo. Stn	120.1	V. Good	6.35	V. Good	39.4	Moderate	51.0	Moderate
FB36	Ruamahanga R at Mt Bruce	126.3	V. Good	6.50	V. Good	56.6	Moderate	57.2	Moderate
FB37	Ruamahanga R at Dble Bridges	117.6	Good	6.10	V. Good	46.8	Moderate	54.7	Moderate
FB38	Ruamahanga R at Te Ore Ore	112.2	Good	4.68	Fair	47.4	Moderate	31.7	Moderate
FB39	Ruamahanga R at Gladstone Br	107.4	Good	5.47	Good	41.8	Moderate	27.9	Moderate
FB40	Ruamahanga R at Waihenga Br	110.2	Good	5.73	Good	45.8	Moderate	32.7	Moderate
FB41	Kopuaranga S at Stewarts	103.9	Good	4.07	Fair	46.6	Moderate	28.6	Moderate
FB43	Whangaehu R 250 u/s confl.	87.1	Fair	4.59	Fair	21.3	Moderate	4.29	Poor
FB44	Waipoua R at Colombo Rd Br	101.4	Good	4.79	Fair	43.0	Moderate	25.0	Moderate
FB45	Waingawa R at South Rd	117.3	Good	6.22	V. Good	51.2	Moderate	54.9	Moderate
FB47	Waiohine R at Gorge	131.0	V. Good	6.83	V. Good	64.5	V. Good	72.8	V. Good
FB48	Waiohine R at Bicknells	115.1	Good	6.24	V. Good	51.6	Moderate	56.0	Moderate
FB49	Mangatarere R at SH2	96.6	Fair	4.63	Fair	34.9	Moderate	11.0	Moderate
FB50	Huangarua R at Ponatahi Br	102.9	Good	5.26	Good	37.9	Moderate	21.2	Moderate
FB51	Tauherenikau R at Websters	113.8	Good	5.10	Good	43.1	Moderate	31.7	Moderate

4.4.3 MCI

The majority (61.9 %) of RSoE sites had a mean MCI score between 80 and 120, translating to a grade of "good" or "fair" (Table 4.8). Of the remaining sites, eleven (26.1 %) received a grade of "very good" and five (11.9 %) received a grade of "poor".

At a REC level, sites with the highest scores were located on high or low elevation river and stream reaches with a cool wet climate and indigenous forest cover (Figure 4.11). These sites included the Wainuiomata River at Manuka Track (142.6), the Waitohu Stream at Water Supply Intake (137.1), and the Waikanae River at Reikorangi Bridge (136.0). In contrast, the sites with the lowest scores were located in low elevation urban catchments; for example the Ngauranga Stream 400 m above Mouth (59.0), Owhiro Stream at Mouth (69.0), and Porirua Stream at Wall Park (75.3).

4.4.4 SQMCI

In contrast with the MCI scores, mean SQMCI scores exhibited a more even spread with 33.3 % and 28.6 % of sites recording grades of "very good" and "poor" respectively. As with the MCI scores, sites draining high or low elevation river and stream reaches with a cool wet climate and indigenous forest cover had higher scores than those draining low elevation pastoral or urban catchments (Figure 4.11). The Waitohu Stream at Water Supply Intake recorded the highest mean score over the reporting period (7.49), and the Ngauranga Stream 400 m above Mouth the lowest (2.15).

4.4.5 % EPT (taxa)

The majority (80.9 %) of RSoE sites had a mean EPT (taxa) score between 10 and 60%, translating to a "moderate" grade (Table 4.8). Just three sites had a grade of "poor"; the Ngauranga Stream 400 m above Mouth (5.25 %), Owhiro Stream at Mouth (7.52 %), and Porirua Stream at Wall Park (9.54 %). Again, sites draining high or low elevation river and stream reaches with a cool wet climate and indigenous forest cover had higher scores than those draining low elevation pastoral or urban catchments (Figure 4.11).

4.4.6 % EPT (individuals)

EPT (individuals) scores differed slightly from EPT (taxa) scores; although the majority (61.9 %) of RSoE sites had mean scores corresponding with a "moderate" grade, there were a greater number of sites assigned "good" and "poor" grades (21.4 % and 16.7 % respectively). The Waitohu Stream at Water Supply Intake recorded the highest mean score (80.7 %), and the Pauatahanui Stream at Elmwood Bridge the lowest (0.91 %).

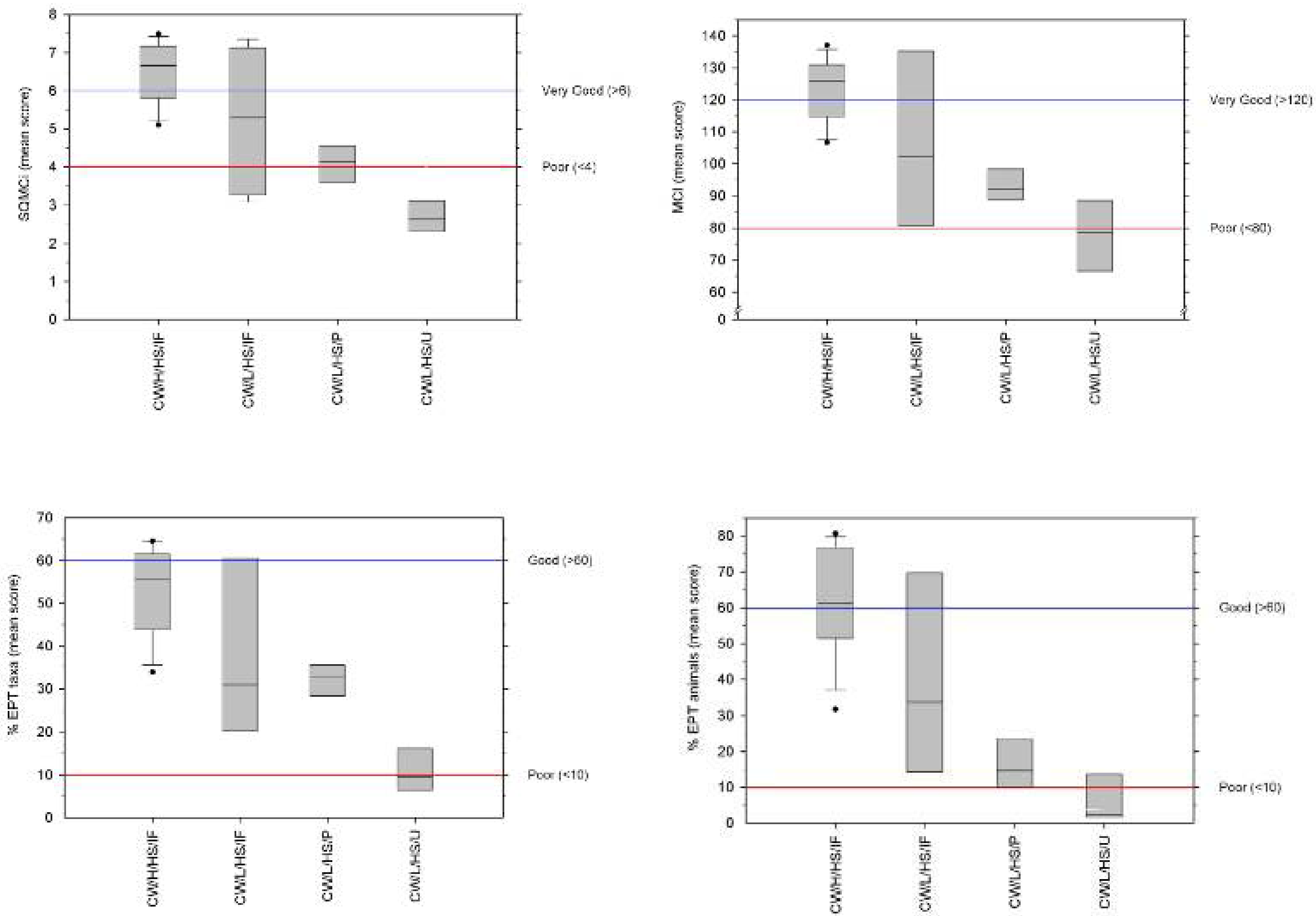


Figure 4.11: Mean MCI, SQMCI, % EPT (taxa) and % EPT (individuals) scores across selected REC classes, based on monitoring over 1999-2003 inclusive. Note axis break on MCI plot.

4.4.7 Synthesis

Mean scores across the four biotic indices were highly correlated; sites that scored well in one index generally scored well in the other indices. This was confirmed by both Spearman Rank Order Correlations and Pearson linear correlations (Appendix 5).

The 10 RSoE sites with the highest index scores are in cool wet-very wet high elevation (seven sites) or low elevation (three sites) river and stream reaches associated with the Tararua, Rimutaka and Aorangi Ranges. As a result, all have their upstream catchments in unmodified indigenous forest cover and share similar geology. The Waitohu Stream at Water Supply Intake had the highest scores across all four of the indices (Figure 4.12).

The majority of RSoE sites that had good or fair scores across the four indices drain low elevation pastoral catchments, although several sites with these scores were in catchments dominated with indigenous forest cover (e.g., Otaki River at Mouth). The lowest index scores were found at low elevation RSoE sites with similar climate (cool and wet) and geology (hard sedimentary). However there is variation in the dominant land cover (Figure 4.12); three sites are in predominantly indigenous forest catchments, two sites are pastoral, and five sites have a high proportion of urban land cover. The poor scores associated with two sites under indigenous forest cover – the Wainuiomata River upstream of White Bridge and at the Golf Course – are attributed largely to the discharge of treated municipal wastewater from the Wainuiomata WWTP during most of the reporting period.

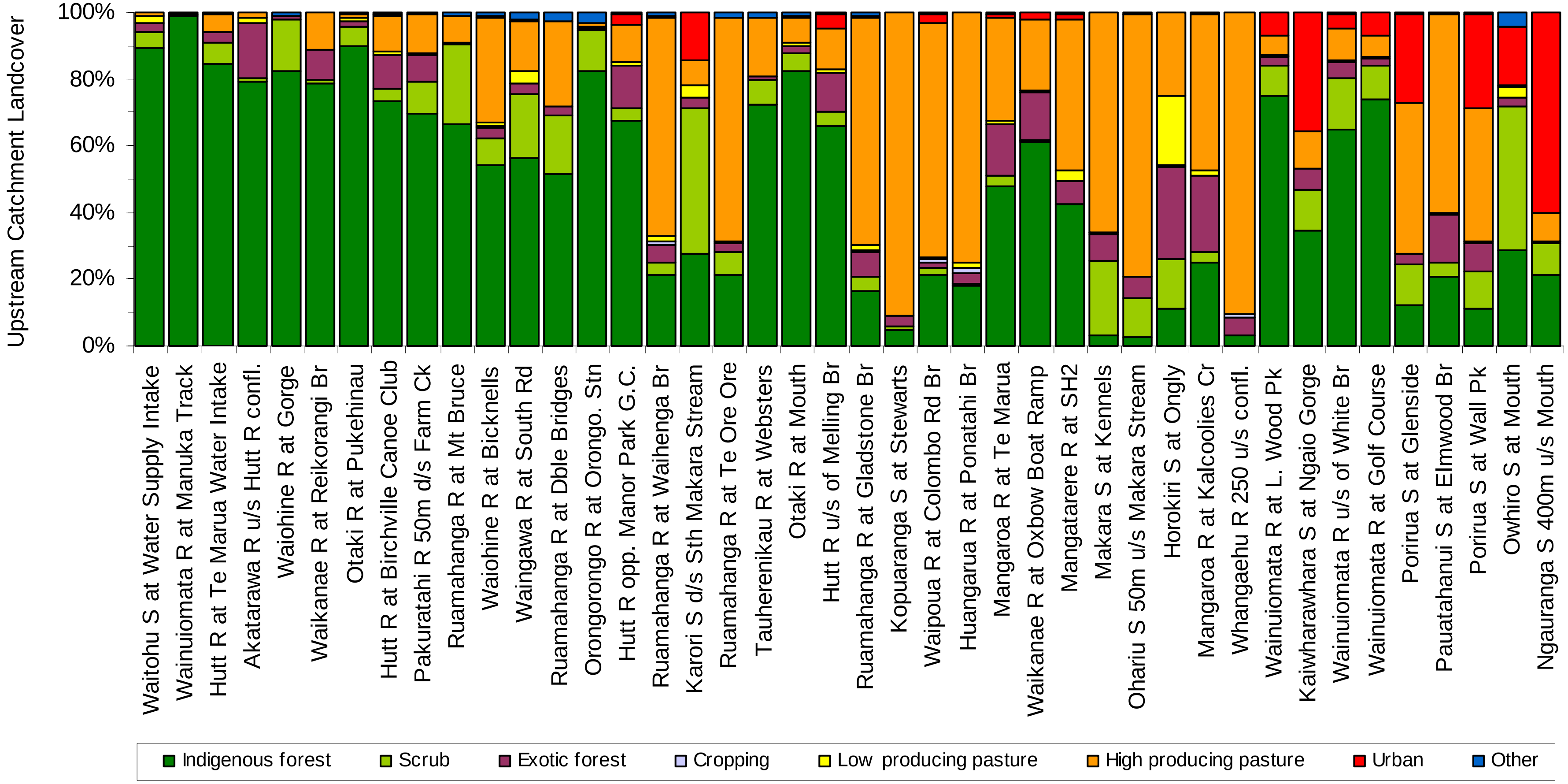


Figure 4.12: RSoE sites ranked from highest (left) to lowest macroinvertebrate community health, and key land cover classes in the upstream catchment area, as derived from the Landcover Database (MfE 2001).

4.5 Discussion

4.5.1 Correlation between water quality and macroinvertebrate health

Even with the inclusion of a microbiological variable in the WQI, there was a reasonable correlation between the WQI and macroinvertebrate community health (Figure 4.13). Of the 10 RSoE sites with the highest scores across the four macroinvertebrate indices, eight were classified as having very good water quality using the WQI, while the other two were classified as having good water quality. All eight of the other RSoE sites in the very good category for water quality, had very good or good mean MCI and/or SQMCI scores.

Macroinvertebrate data only exists for seven of the 12 sites classified with poor physico-chemical and water quality over the reporting period. Of these seven sites, three recorded poor macroinvertebrate health scores and four recorded fair macroinvertebrate health scores.

The lack of agreement between the water quality and macroinvertebrate grades found at some sites suggests that another water quality variable not encompassed within the WQI (e.g., temperature, heavy metals) or some other factor (e.g., habitat quality) is more strongly influencing the instream macroinvertebrate community. For example the Wainuiomata River at Leonard Wood Park recorded good water quality under the WQI but scored fair MCI and poor SQMCI grades. This is discussed further in Section 6.1.2.

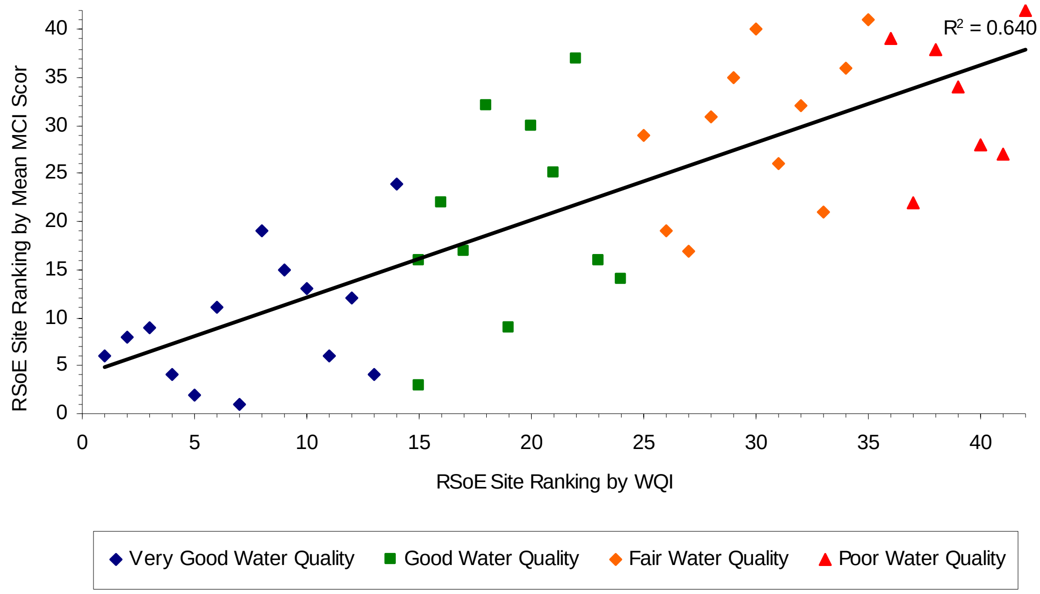
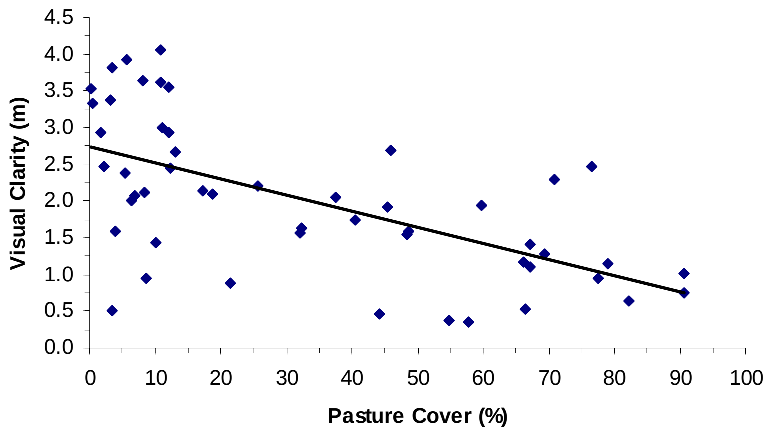


Figure 4.13: RSoE sites ranked from highest to lowest physico-chemical and microbiological water quality (based on the WQI) and macroinvertebrate health (based on mean MCI scores). Data applies to the 42 sites monitored for both water quality and macroinvertebrate health over the reporting period.

4.5.2 Spatial patterns

Physico-chemical and microbiological water quality results for the July 1997 to July 2003 reporting period show a clear spatial pattern related to climate, source of flow, geology and, in particular, land cover (Figure 4.14). Consistent with monitoring results from elsewhere (e.g., Larned et al. 2005), water quality is highest at RSoE sites located on cool wet, hill-fed river and stream reaches with hard sedimentary geology and unmodified indigenous forest cover. These sites tend to be associated with the Tararua, Rimutaka and Aorangi Ranges. Water quality is generally lower in lowland reaches under indigenous forest cover, and lower again at sites in pastoral catchments. Water quality is particularly poor at some sites draining dairy catchments. Overall, water quality is poorest at sites draining urban catchments.

Macroinvertebrate community health over 1999-2003 exhibits a similar spatial pattern to physico-chemical and microbiological water quality. RSoE sites with the highest macroinvertebrate scores are located on hill-fed river and stream reaches with a high proportion of indigenous forest cover in their upstream catchments (Figure 4.15).



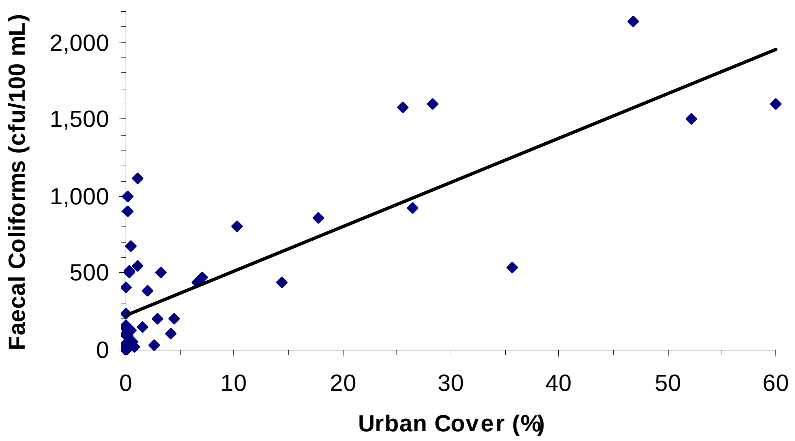


Figure 4.14: Correlation between (i)median visual clarity values recorded at RSoE sites (from routine monitoring undertaken over July 1997-July 2003 inclusive) and the percentage of pasture cover in the upstream catchment (top) and (ii)median faecal coliform counts and the percentage of urban cover (bottom). The solid black line in each plot shows the overall trend.

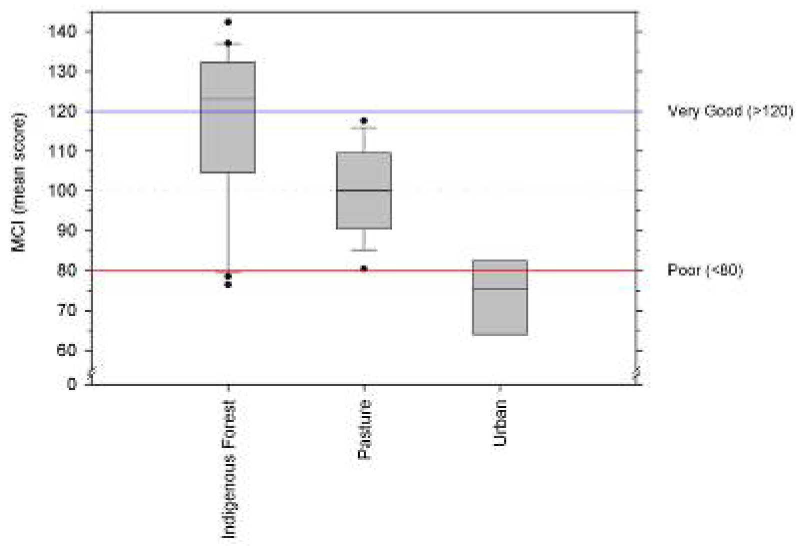


Figure 4.15: MCI scores across the three main REC land cover classes represented in the RSoE site network; indigenous forest, pasture and urban. Note axis break.

Monitoring records from the five monitoring sites on the Ruamahanga River and, to a lesser extent, the four sites on the Hutt River, demonstrate the decline in water quality with distance downstream from high elevation forested river reaches to low elevation reaches draining forested, pastoral or urban catchments.

(a) Ruamahanga River

The Ruamahanga River was monitored at five locations over the reporting period; Mount Bruce (21 km from source of flow), Double Bridges (35.5 km), Te Ore Ore (47 km), Gladstone (65 km) and Waihenga (99.5 km). The monitoring sites and associated water quality and macroinvertebrate health grades are summarised in Table 4.9.

Table 4.9: WQI and macroinvertebrate health grades for the five RSoE sites located on the Ruamahanga River, based on compliance of median values from monthly monitoring over July 1997 to July 2003 inclusive with guideline values.

Site No.	Site Name	WQI Grade & Site Ranking (51 sites)	Macroinvertebrate health ranking* (42 sites)	MCI Grade	SQMCI Grade
FB36	Ruamahanga R at Mt Bruce	Very Good (3)	10	Very Good	Very Good
FB37	Ruamahanga R at Dble Bridges	Very Good (12)	13	Good	Very Good
FB38	Ruamahanga R at Te Ore Ore	Good (23)	18	Good	Fair
FB39	Ruamahanga R at Gladstone Br	Fair (27)	22	Good	Good
FB40	Ruamahanga R at Waihenga Br	Fair (28)	16	Good	Good

* Based on mean scores across all four biotic indices

The decline in physico-chemical and microbiological water quality with distance downstream from Mount Bruce is seen more clearly by examining the median values of selected water quality variables; visual clarity, turbidity, and dissolved and total nutrient concentrations (Table 4.5, Figure 4.16).

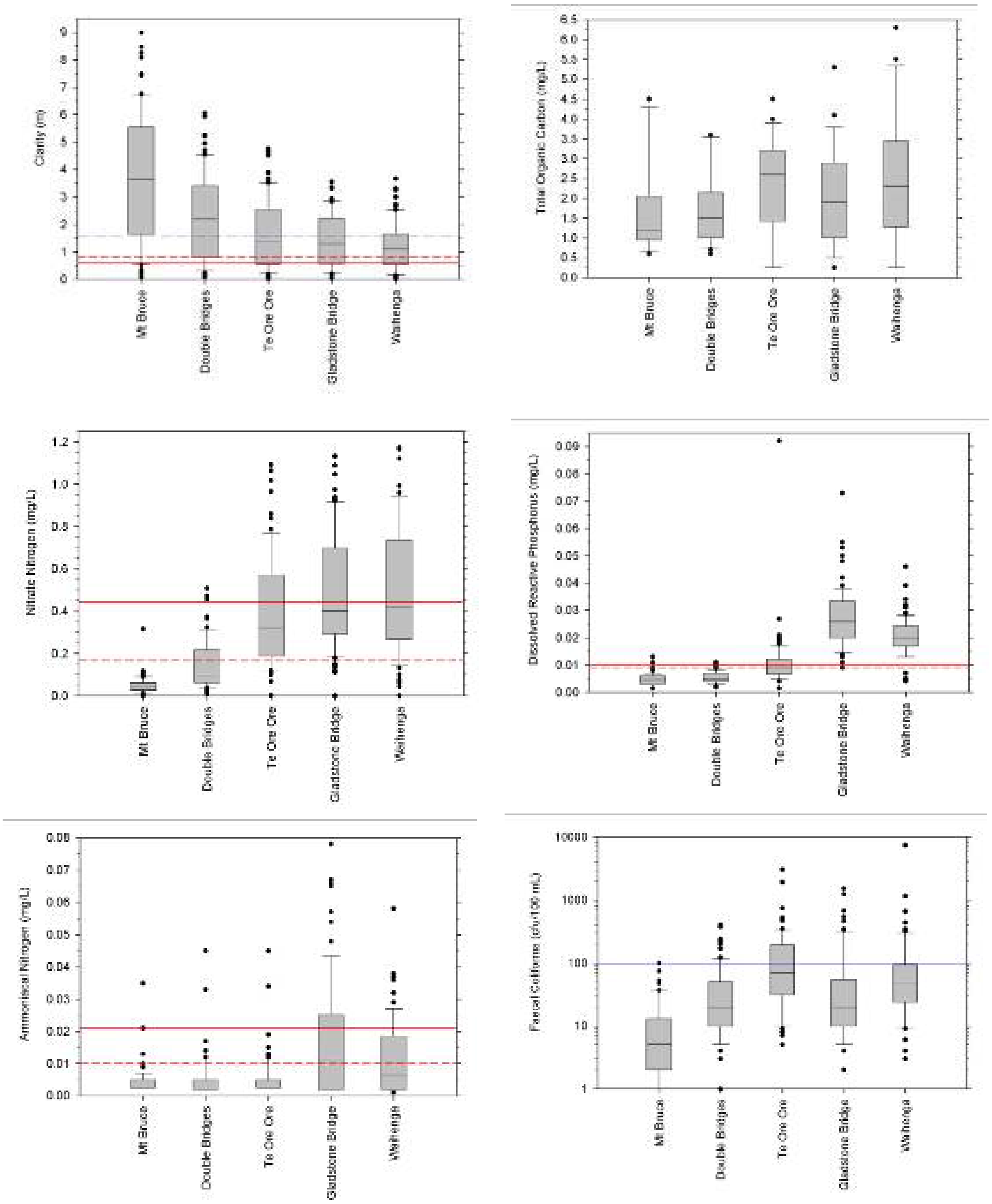


Figure 4.16: Visual clarity, total organic carbon, dissolved nutrient and faecal coliform values recorded at RSoE sites on the Ruamahanga River during routine monthly monitoring over July 1997 to July 2003 inclusive.

- - - - - - - ANZECC (2000) Upland Trigger Value

———— ANZECC (2000) Lowland Trigger Value

- - - - - - - MfE (1994) Guideline for Bathing

———— ANZECC (2000) Stockwater Trigger Value

At Mount Bruce, water quality consistently complied with guideline values. ANZECC (2000) default trigger values were exceeded at times at both Double Bridges and Te Ore Ore, although all median values complied with the default trigger values. Further downstream at Gladstone Bridge and Waihenga, the number of exceedances was higher and, in the case of dissolved reactive phosphorus, concentrations for both sites consistently exceeded the ANZECC (2000) default trigger value of 0.010 mg/L (Figure 4.17). Median dissolved reactive phosphorus and ammoniacal nitrogen concentrations were lower at Waihenga than at Gladstone Bridge, despite the former site being located further downstream. Median visual clarity values at Te Ore Ore, Gladstone Bride and Waihenga all exceeded the MfE (1994) bathing guideline of 1.6 m.

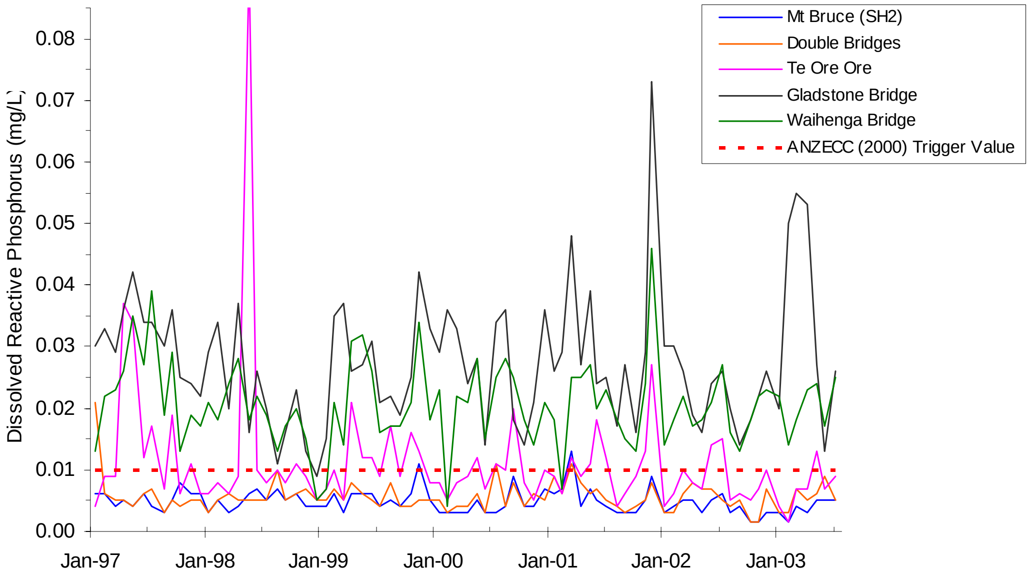


Figure 4.17: Dissolved reactive phosphorus concentrations recorded at RSoE sites on the Ruamahanga River during routine monthly monitoring over July 1997 to July 2003 inclusive.

Mean MCI, SQMCI, % EPT (taxa) and % EPT (animals) also decline with distance downstream (Table 4.10). With the exception of SQMCI scores, Gladstone Bridge recorded the lowest mean index scores.

Table 4.10: Mean macroinvertebrate index scores (± 1 standard error) for RSoE monitoring sites on the Ruamahanga River sampled annually over 1999-2003 inclusive.

Site Name	MCI		SQMCI		% EPT (taxa)		% EPT (animals)	
	Mean Score	SE	Mean Score	SE	Mean Score	SE	Mean Score	SE
Mt Bruce	126.3	5.7	6.50	0.47	56.6	3.8	57.2	5.0
Double Bridges	117.6	3.2	6.10	0.49	46.8	4.6	54.7	10.4
Te Ore Ore	112.2	3.9	4.68	0.79	47.4	2.0	31.7	13.7
Gladstone Bridge	107.4	3.4	5.47	0.46	41.8	2.3	27.9	6.3
Waihenga	110.2	3.0	5.73	0.34	45.8	4.6	32.7	11.1

The decline in water quality and macroinvertebrate health with distance downstream is attributed to changes in land cover and land use practices, and the influence of point source municipal wastewater discharges. Downstream of Mount Bruce, indigenous forest and scrub cover gives way to increasing pastoral cover that supports various agricultural land uses (Figure 4.18). Overland runoff from farms and direct stock access to tributaries are likely to contribute significantly to increased instream contaminant loads. Major tributaries monitored under the RSoE programme with poor water quality attributed largely to agricultural practices include the Kopuaranga Stream (enters the Ruamahanga River above Te Ore Ore), Whangaehu River (enters above Gladstone Bridge), and Mangatarere Stream (enters via the Waiohine River just south of Carterton). Water quality in the Mangatarere Stream is also influenced by the discharge of municipal wastewater from Carterton.

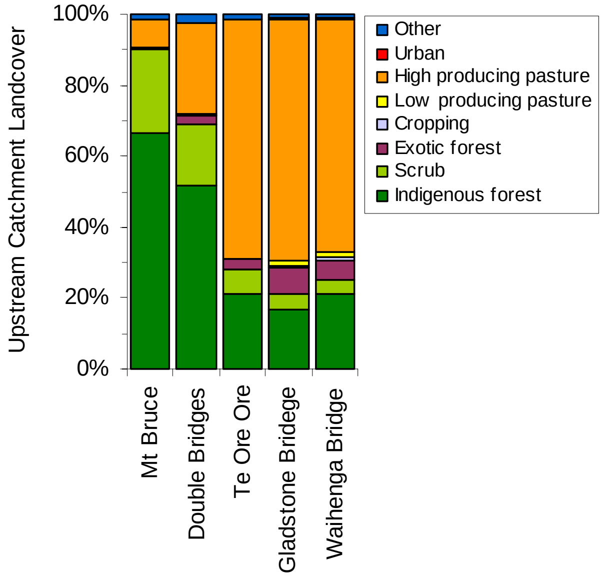


Figure 4.18: Predominant land cover types in the catchment area upstream of each of the five RSoE monitoring sites on the Ruamahanga River.

In addition to agricultural inputs, treated municipal wastewater from four of the five main townships in the Wairarapa, along with treated wastewater from Rathkeale College north of Masterton, is discharged into the Ruamahanga River, either directly or indirectly via its tributaries. Analysis of the July 1999-June 2001 monitoring data for the four municipal wastewater discharges by Watts (2001), indicates that some of these discharges contribute significant loads of nutrients (particularly phosphorus) into the Ruamahanga River system, relative to background loads. The most significant of these discharges is the Masterton wastewater discharge which enters the river via the Makoura Stream, approximately 7 km downstream of Te Ore Ore; Watts (2001) estimated that this discharge contributes 58 tonnes/year of total nitrogen and 12.5 tonnes/year of total phosphorus, compared with an estimated background loading in Makoura Stream of 16 tonnes/year and 0.16 tonnes/year of nitrogen and phosphorus respectively (Table 4.11).

Table 4.11: Estimated annual total nitrogen and total phosphorus loads from major wastewater discharges to the Ruamahanga River system.

Township & Estimated Population	Receiving Waters	Nearest RSoE Monitoring Site	Estimated Nutrient Load (Tonnes/yr)		Estimated Background Nutrient Load (Tonnes/yr)	
			Total N	Total P	Total N	Total P
Rathkeale College	Ruamahanga River below confluence with Kopuaranga Stream.	Te Ore Ore (downstream)	No data	No data	No data	No data
Masterton (17,800)	Makoura Stream, about 100 m upstream of Ruamahanga River.	Gladstone Bridge (downstream)	58	12.5	16	0.1
Carterton (4,500)	Mangatarere Stream*, which flows into the Waiohine River below SH 2 and then the Ruamahanga River	Waihenga (downstream)	7.4	1.6	109	2.8
Greytown (2,000)	Papawai Stream, about 1.5 km upstream confluence with Ruamahanga River	Waihenga (downstream)	5.0	1.6	20.6	0.4
Martinborough (1,500)	Ruamahanga River, 2.5 km downstream of Waihenga.	Waihenga	3.6	1.8	1,934	98

*Summer land-based disposal trialled since 2003/2004.

As well as effects on the immediate receiving waters, Watts (2001) identified that several municipal discharges were having a more than minor effect on water quality in the Ruamahanga River:

- Masterton: water quality analysis identified a significant increase in ammoniacal-nitrogen and dissolved reactive phosphorus concentrations downstream of the Makoura Stream confluence and a conspicuous change in water clarity.

- Martinborough: water quality analysis identified a significant increase in faecal coliform and *E. coli* bacteria counts, together with a significant increase in dissolved reactive phosphorus, nitrate nitrogen and ammoniacal nitrogen concentrations downstream of the discharge to the Ruamahanga River.

With intensive agricultural activity in the reaches south of Waihenga, together with direct nutrient inputs from Martinborough municipal wastewater, further degradation in water quality is expected downstream of Waihenga. This is likely to be observed in future RSoE monitoring; the monitoring site at Waihenga was replaced with a new site further downstream at Pukio in September 2003.

4.6 The Hutt River

The Hutt River was monitored at four locations over the 1997-2003 reporting period; Te Marua water intake, Birchville Canoe Club, opposite the Manor Park Golf Course, and upstream of Melling Bridge. The water quality grades and macroinvertebrate health scores for these sites are summarised in Table 4.12.

Table 4.12: WQI and macroinvertebrate health grades for the four RSoE sites located on the Hutt River, based on compliance of median values from monthly monitoring over July 1997 to July 2003 inclusive with guideline values.

Site No.	Site Name	WQI Grade & Site Ranking (51 sites)	Macroinvertebrate health ranking based on mean scores across all 4 biotic indices (42 sites)	MCI Grade	SQMCI Grade
22	Hutt R at Te Marua Water Intake	Very Good (4)	3	Very Good	Very Good
23	Hutt R at Birchville Canoe Club	Good (19)	8	Very Good	Very Good
24	Hutt R opp. Manor Park G.C.	Good (17)	15	Good	Good
25	Hutt R u/s of Melling Br	Good (16)	21	Good	Good

The WQI and macroinvertebrate community health grades both indicate that there is a small decline in water quality in the Hutt River with distance downstream. This is seen more clearly by examining the actual median values for selected water quality variables (refer Table 4.5) and mean scores across the four key macroinvertebrate indices (Table 4.13). The decline in water quality is most evident in visual clarity, turbidity, nitrogen and faecal bacteria concentrations, with Manor Park having lower water quality than Melling Bridge (Figure 4.19). Overall the decline is less marked than that in the Ruamahanga River, a reflection of less intensive land-use in the catchment (Figure 4.20).

Table 4.13: Mean macroinvertebrate index scores (± 1 standard error) for RSoE monitoring sites on the Hutt River sampled annually over 1999-2003 inclusive.

Site Name	MCI		SQMCI		% EPT (taxa)		% EPT (animals)	
	Mean Score	SE	Mean Score	SE	Mean Score	SE	Mean Score	SE
Te Marua Water Intake	132.6	4.1	7.25	0.21	62.3	4.5	77.1	4.7
Birchville Canoe Club	125.7	1.8	7.19	0.21	55.2	3.8	77.4	4.8
Opp. Manor Park G.C.	109.7	3.0	5.45	0.50	46.0	2.8	52.8	8.5
Upstream of Melling Br	103.8	1.4	5.29	0.50	39.1	2.4	43.3	9.1

The only variable that exceeded guideline values on a regular basis was faecal coliforms at Birchville, Manor Park and Melling Bridge (Figure 4.18). This may in part be due to stormwater discharges and sewer overflows. The Hutt City Council holds resource consents authorising sewer overflows into the Hutt River at Silverstream, Manor Park, Taita and Barber Grove (Moera). These overflows occur at times when the sewerage system is overloaded by stormwater infiltration during heavy rain. Diffuse-source runoff is also likely to influence water quality in parts of the Hutt River, particularly in tributaries draining agricultural catchments (e.g., Mangaroa River).

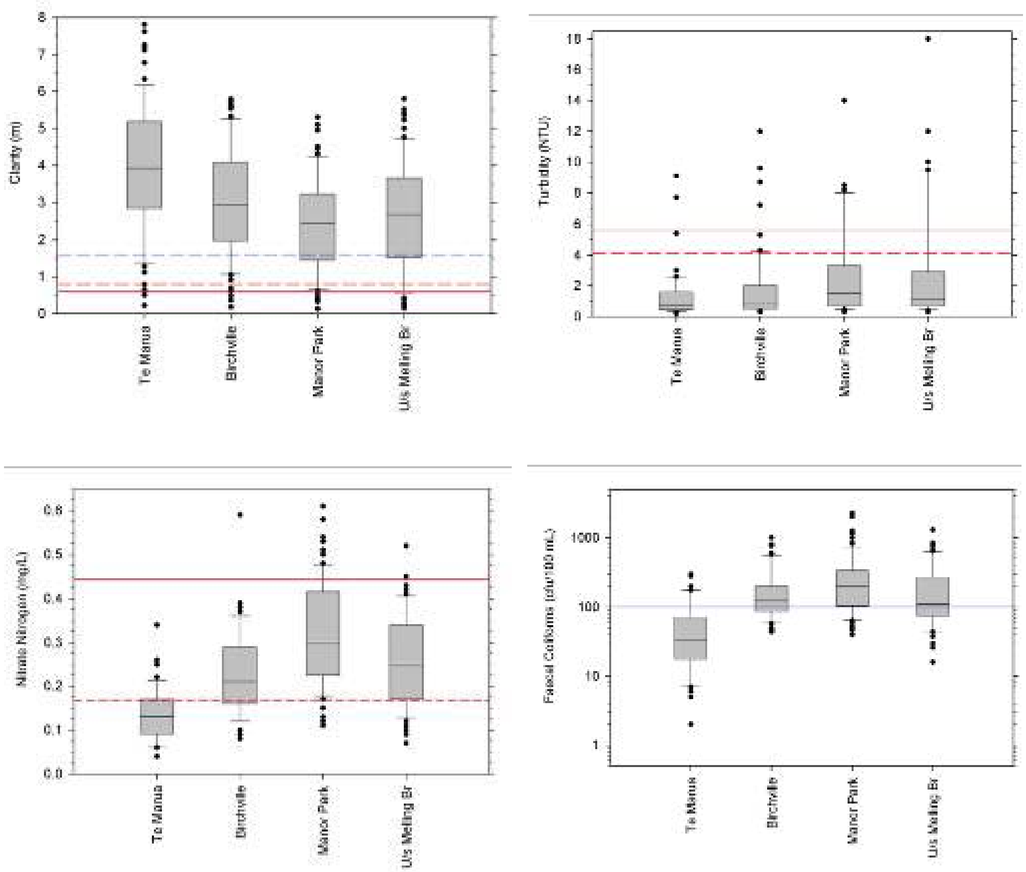


Figure 4.19: Visual clarity, turbidity, nitrate nitrogen, and faecal coliform values recorded at RSoE sites on the Hutt River during routine monthly monitoring over July 1997 to July 2003 inclusive.

- - - - - - - ANZECC (2000) Upland Trigger Value

——— ANZECC (2000) Lowland Trigger Value

- - - - - - - MfE (1994) Guideline for Bathing

——— ANZECC (2000) Stockwater Trigger Value

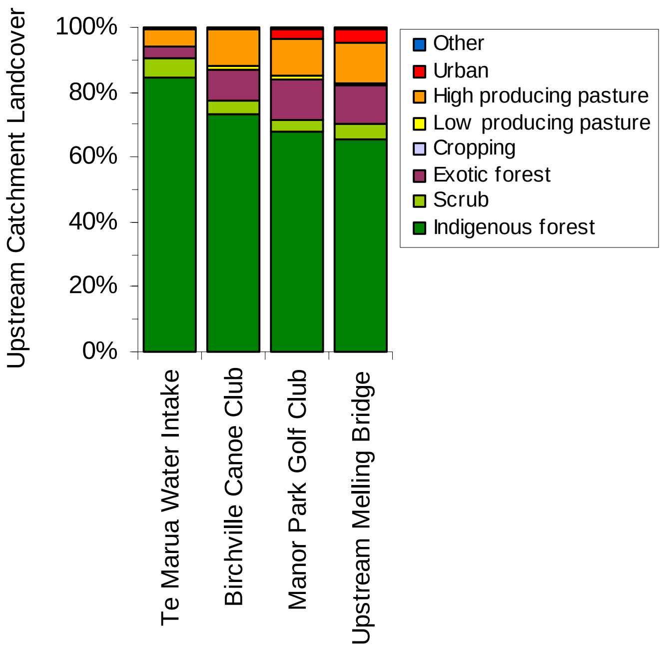


Figure 4.20: Predominant land cover types in the catchment area upstream of the RSoE monitoring sites on the Hutt River.

5. Temporal trends in water quality

The Water Quality Index (WQI) presented in Section 4 provides an indication of the *state* of water quality based on median values of six key water quality variables over the July 1997-July 2003 reporting period. To determine whether water quality has improved or deteriorated over this period, trend analyses were performed on selected physico-chemical and microbiological water quality data and macroinvertebrate records from each of the 51 RSoE monitoring sites. The results of these analyses are summarised in this section, together with relevant observations drawn from recent analyses of water quality records from New Zealand's National River Water Quality Network (Scarsbrook et al., unpublished data).

5.1 Approach to analysis

5.1.1 Water quality data

Water quality data for each of the 51 RSoE sites monitored over the period 1 September 1997 to 31 August 2003 inclusive were used to assess temporal trends in surface water quality across the Wellington region. This reporting period differs slightly from that used to assess spatial trends. Earlier and more recent data was excluded for the reasons outlined in Sections 2.3-2.4.

(a) Data adjustment

During data processing, any water quality variables reported as less than or greater than detection limits were replaced by values one half of the detection limit or the detection limit respectively (e.g., a value of <2 became 1, while a value of >400 became 400).

As data records were assessed and interpreted on a site by site basis, no adjustment was made for the different detection limits employed in the analysis of water samples from sites in the western half of the Wellington region and sites in the Wairarapa during the reporting period (refer Section 4.1.1).

(b) Trend analysis

Trends in selected water quality variables were examined using the Seasonal Kendall trend test. This is a non-parametric statistical method widely used in the analysis of trends in water quality in New Zealand (e.g., Scarsbrook et al. 2003, Larned et al. 2004, Vant & Smith 2004). Its strength lies in its ability to deal with the marked seasonal variability which is often a major feature of water quality records. The magnitude of the trend is determined by the Seasonal Kendall slope estimator (SKSE); the greater the slope (irrespective of whether the slope is negative or positive), the greater the magnitude of the trend.

In rivers and streams, a further source of variability is the influence of flow on certain water quality variables at the time of sampling. This variability may obscure any real underlying trend. It is therefore preferable to "flow-adjust" water quality records prior to trend analysis.

In this report, trend analysis was performed on raw data from each of the 51 RSoE sites and on flow-adjusted data from the 14 sites where flow and surface water quality records coincided. A trend was deemed to be statistically significant (i.e., unlikely to be due to chance) if the *p* value was less than 0.05 or 5%. Further details on the Seasonal Kendall trend test and flow-adjustment methods are provided in Appendix 6.

(c) Cautionary notes

- A formal quality assurance (QA) system is not in place for water quality data collected under the RSoE programme. The only changes made to raw data drawn from Greater Wellington's water quality database were the removal of gross outliers, where detected.
- The use of raw – as opposed to flow-adjusted – water quality records for the majority of trend analyses limits the ability to determine the magnitude and statistical significance of trends which are explained by factors other than flow (e.g., changes in upstream land-use). In analysing trends in river water quality in the Waikato region, Vant and Smith (2004) identified 120 significant trends in raw water quality records which were not evident in the flow-adjusted records. Similarly, Warr (2002b) illustrated for the Waikanae River at Reikorangi that significant seasonal variation in some water quality variables (e.g., turbidity) was not present in flow adjusted records, suggesting that seasonal flow patterns are the main driver of fluctuations in water quality in that river.
- Not all variables were monitored for the full reporting period at all sites, notably total nitrogen, total phosphorus, 5-day biochemical oxygen demand (BOD_5), and total organic carbon (refer Table 2.1, Section 2.4).

5.1.2 Biological data

Death and Death (2005), on behalf of Greater Wellington, assessed temporal trends in macroinvertebrate community health using data obtained from annual monitoring over 1999 to 2003 inclusive (10 sites) and 1999 to 2004 inclusive (32 sites). Refer to Appendix 7 for further details.

(a) Trend analysis

Linear trends in the four macroinvertebrate indices presented in Section 4 were examined using the non-parametric Spearman rank correlation method with a statistically significant trend indicated by $p<0.1$. There were too few data points to examine statistically for non-linear trends but any potential trends could be identified visually in the graphs (Death and Death 2005).

(b) Cautionary notes

- Macroinvertebrate sampling and processing methods changed during the reporting period and these changes may have influenced the trend analyses (refer Appendix 3).

- Six sites were relocated upstream during the reporting period, following the RSoE programme review by Warr (2002). The shift in sampling locations may have influenced the macroinvertebrate records and therefore the trend analyses performed for these sites (refer to Appendix 7).

5.2 Physico-chemical and microbiological water quality

The results of Seasonal Kendall trend test results for the 51 RSoE monitoring sites are summarised in Table 5.1 and presented in full in Appendix 8.

Table 5.1: Summary of statistically significant (***p***<0.05) trends present in raw and flow-adjusted physico-chemical and microbiological water quality variables at RSoE sites monitored at monthly intervals over 1 September 1997 to 31 August 2003 inclusive.

Variable	Significant Trends (No. of sites)			
	Raw Data (51 sites)		Flow-adjusted Data (14 sites)	
	Increasing	Decreasing	Increasing	Decreasing
Dissolved Oxygen (% saturation)	8	0	3	0
Temperature	0	2	0	0
pH	2	6	2	3
Conductivity	12	1	3	1
Visual Clarity	3	2	0	0
Turbidity	1	6	0	1
BOD_5	0	2	1	2
Total Organic Carbon	0	5	0	0
Faecal coliforms	2	12	0	2
Nitrate Nitrogen	1	8	0	2
Ammoniacal Nitrogen	2	7	2	2
Total Nitrogen	1	8	0	1
Dissolved Reactive Phosphorus	3	5	0	3
Total Phosphorus	3	5	0	2

It can be seen that:

- Significant increasing trends in dissolved oxygen concentrations were observed at eight sites (raw data). These increases represent improvements in water quality.
- At all but two sites, there was no significant temporal trend in water temperature.
- Conductivity showed a significant increasing trend at over 20 % of sites; based on the raw data this included seven sites draining predominantly indigenous forest and five sites draining predominantly pastoral catchments. The magnitude of the increases was typically small, ranging from 1.01 uS/cm per year to 3.36 uS/cm per year in the raw data (median increase 1.61 uS/cm) and from 0.599 uS/cm per year to 1.06 uS/cm per year in the flow adjusted data.
- Significant trends in faecal coliform counts were observed at 14 sites (raw data). At 12 of these sites, including seven sites draining pastoral catchments, faecal bacteria counts decreased. The reductions ranged from -2.0 cfu/100 mL per year to -348.7 cfu/100 mL per year) and represent improvements in water quality.

- With the exception of flow adjusted ammoniacal nitrogen records, significant increasing trends in nutrient concentrations were observed at less than 10% of sites. In contrast, significant decreasing trends in nutrient concentrations were observed at 10 % or more sites, with eight sites showing decreasing nitrate nitrogen concentrations (raw data). These reductions represent improvements in water quality.

In many cases, statistically significant trends were small and not considered *ecologically significant*; the annual or long-term change indicated by the trend may not have a substantial effect on the river or stream ecosystem. For example, flow-adjusted ammoniacal nitrogen records for the Waiohine River at the Gorge showed a statistically significant increase over the reporting period, but concentrations in the river are typically below detection and the increase was very small (0.000014 mg/L per year). Selected sites that exhibited significant changes in water quality over the reporting period are discussed in Sections 5.2.1 to 5.2.7. In most cases, these changes represent improvements in water quality related to the removal of point source discharges. Temporal trends, significant or otherwise, in the Hutt River and Ruamahanga River are also presented.

5.2.1 Waitohu Stream (Norfolk Crescent)

Significant decreases in BOD_5 (-0.703 mg/L per year), ammoniacal nitrogen (-0.026 mg/L per year) and nitrate nitrogen (-0.050 mg/L per year) concentrations were observed in the lower Waitohu Stream over the 1 September 1997 to 31 August 2003 reporting period (Figure 5.1). Significant decreases were also observed in turbidity values (-1.26 NTU per year) and faecal coliform counts (-79.2 cfu/100 mL per year) over this period, while visual clarity increased (0.042 m per year) (Figure 5.2). The improvement in water quality is attributed to the removal of point source discharges of dairy shed effluent to the stream between 1999 and 2001; dairy shed effluent is now discharged to land. Progressive fencing of stretches of the lower stream is also likely to have contributed to improvements in water quality.

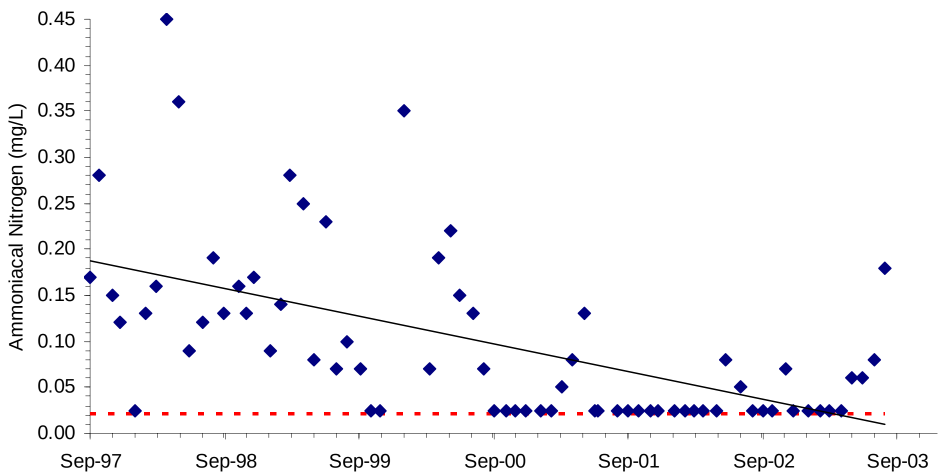


Figure 5.1: Ammoniacal nitrogen concentrations (non flow-adjusted data) recorded in the Waitohu Stream at Norfolk Crescent over 1 September 1997 to 31 August 2003 inclusive. The solid black line shows the overall trend in the data record and the red dashed line indicates the ANZECC (2000) lowland trigger value.

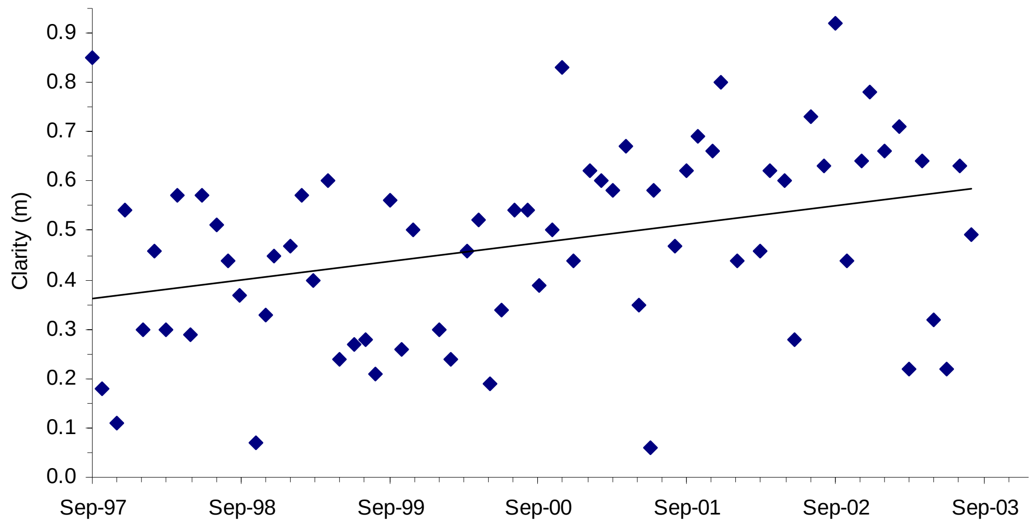


Figure 5.2: Visual clarity measurements (non flow-adjusted data) recorded in the Waitohu Stream at Norfolk Crescent over 1 September 1997 to 31 August 2003 inclusive. The solid black line shows the overall trend in the data record.

5.2.2 Mangaone Stream

A significant improvement in water quality was observed in the Mangaone Stream at Sims Road Bridge over the reporting period, as illustrated by an increase in visual clarity (0.048 m per year) and decreasing trends in the concentrations of the following variables; turbidity (-1.027 NTU per year), BOD_5 (-0.262 mg/L per year), total organic carbon (-1.073 mg/L per year), ammoniacal nitrogen (-0.025 mg/L per year) and faecal coliforms (-348.7 cfu/100 mL per year). The decrease in the faecal coliform counts was dramatic, with the median value dropping an order of magnitude from 2,470 cfu/100 mL over September 1997-August 1998 (n=12) to 470 cfu/100 mL over October 2002 to September 2003 (n=10) (Figure 5.3). The other variable to exhibit a statistically significant change over the reporting period was pH (-0.020 pH units per year).

The improvement in water quality in the lower Mangaone Stream most probably reflects the removal of point source dairy shed effluent discharges; by the end of 1999 five of the six dairy shed discharges to water in the catchment had ceased.

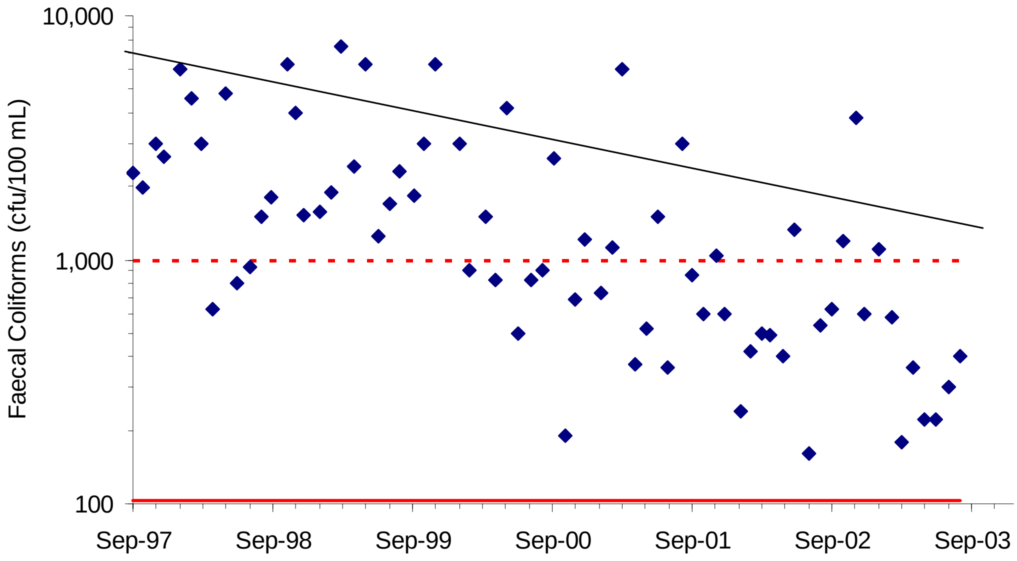


Figure 5.3: Faecal coliform counts (non flow-adjusted data) recorded in the Mangaone Stream at Sims Road Bridge over 1 September 1997 to 31 August 2003 inclusive. The solid black line shows the overall trend in the data record and the dashed and solid red lines indicate the ANZECC (1992) Stockwater Guideline and ANZECC (2000) Stockwater trigger value respectively. Note log-scale and starting point on y-axis.

5.2.3 Ngarara Stream

Nutrient and faecal coliform bacteria concentrations decreased significantly in the Ngarara Stream at Field Way over the reporting period (Figure 5.4); total organic carbon (-3.712 mg/L per year), ammoniacal nitrogen (-0.109 mg/L per year), total nitrogen (-1.665 mg/L per year), dissolved reactive phosphorus (-0.028 mg/L per year), total phosphorus (-0.295 mg/L per year), and faecal coliforms (-187.2 cfu/100 mL per year). These trends represent an improvement in water quality that coincided with the decommissioning of the Waikanae WWTP; up until March 2002, treated municipal wastewater was discharged to the Ngarara Stream via the Black Drain. Wastewater from Waikanae is now pumped to Paraparaumu for treatment and disposal.

Water quality may continue to improve in the future as a result of riparian planting programmes initiated in the lower part of the catchment in 2001 and the recent closure of a dairy farm. The riparian planting is discussed further in Section 6.1.3.

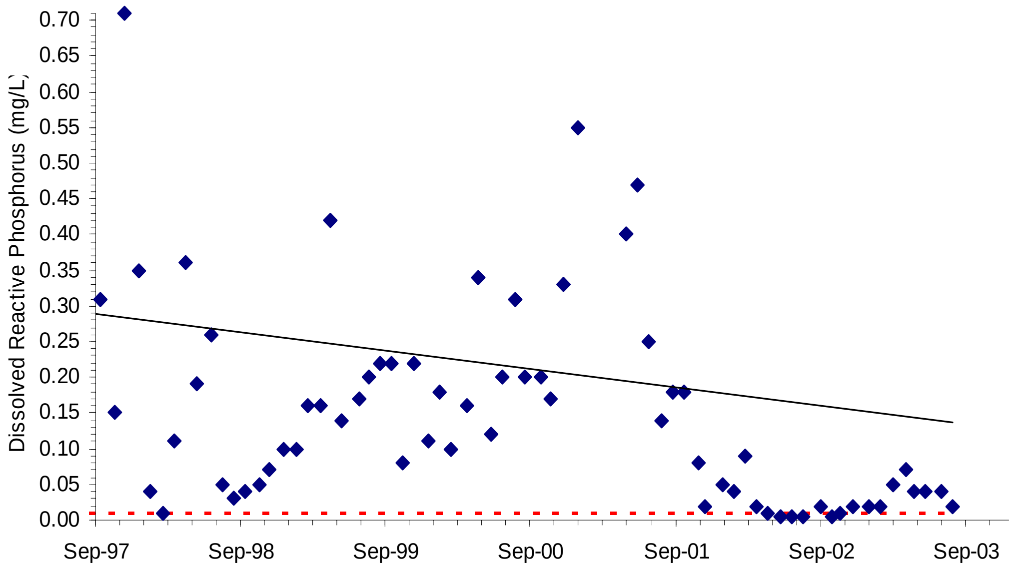


Figure 5.4: Dissolved reactive phosphorus concentrations (non flow-adjusted data) recorded in the Ngarara Stream at Field Way over 1 September 1997 to 31 August 2003 inclusive. The solid black line shows the overall trend in the data record and the red dashed line indicates the ANZECC (2000) lowland trigger value.

5.2.4 Hutt River

Only a few significant trends were observed in the raw and flow adjusted water quality records for the four RSoE sites monitored on the Hutt River over 1 September 1997 to 31 August 2003 inclusive. Raw data from the site at Te Marua showed a small decrease in temperature (-0.293 ˚C/year). This decreasing trend was not present in the flow-adjusted records but other statistically significant trends were; BOD_5 and conductivity increased by a small amount (0.004 mg/L per year and 0.599 uS/cm per year respectively), while pH decreased (-0.017 pH units per year). The site at Birchville showed small but statistically significant increasing trends in conductivity (1.046 uS/cm per year) and faecal coliforms (12.32 cfu/100 mL). These trends were evident in raw data; no flow-adjusted data was available for this site.

Scarsbrook et al. (unpublished data) analysed trends in Hutt River water quality as part of their assessment of water quality records collected from the New Zealand's National River Water Quality Network (NRWQN). This network comprises 77 sites around the country, and includes two sites on the Hutt River near Greater Wellington's RSoE sites; Kaitoke (approximately 8 km upstream of Site FB22 at Te Marua), and Boulcott (approximately 0.7 km upstream of Site FB25 at Melling Bridge). The NRWQN programme includes flow measurements, utilises very low detection limits for some variables and, unlike Greater Wellington's RSoE programme, monitoring sites, variables, and methods have remained consistent over the period of record to date. Consequently the ability to detect trends in water quality over time is more powerful.

Analysis of NRWQN records over 1989 to 2003 inclusive identified small but highly significant ($p<0.01$) decreases in ammoniacal nitrogen concentrations in the Hutt River in both raw and flow adjusted data (-0.000275 mg/L and -0.000312 mg/L per year (flow-adjusted data) at Kaitoke and Boulcott respectively), consistent with national trends (Scarsbrook et al., unpublished data). Some of the other statistically significant trends identified from the data-set include:

- An increase in temperature at Kaitoke (raw data only) and increases in clarity (raw and flow-adjusted data) at both Kaitoke and Boulcoutt. The increases in clarity were 0.140 m and 0.053 m for Kaitoke and Boulcoutt respectively (flow-adjusted data).

- Increases in both raw and flow-adjusted dissolved oxygen concentrations at Kaitoke (0.139 and 0.123 % per year respectively). In contrast, dissolved oxygen concentrations at Boulcott decreased (-0.168 and -0.148 % per year for raw and flow-adjusted data respectively).

- Decreases in both raw and flow-adjusted BOD_5 concentrations (-0.016 and -0.015 mg/L per year respectively) and pH measurements (-0.013 and -0.009 pH units per year respectively) at Boulcott.

- A small increase in nitrate nitrogen concentrations at Kaitoke in both raw and flow-adjusted data (0.00056 and 0.00063 mg/L per year respectively).

- A small decrease in pH at Boulcott in both raw and flow-adjusted data (-0.013 and -0.001 pH units per year respectively).

5.2.5 Wainuiomata River

The Wainuiomata River was monitored at four locations over the reporting period; Manuka Track, Leonard Wood Park, the Wainuiomata Golf Course, and upstream of White Bridge. Significant improvements in water quality were observed at the latter two (downstream) sites, particularly with respect to nutrient concentrations and faecal coliform counts (Table 5.2). A significant increasing trend in dissolved oxygen concentrations was also recorded in raw and flow adjusted records for the Wainuiomata Golf Course; the magnitude of the increase (2.89 % per year, raw data) was considerably larger than the increases observed upstream at Manuka Track and Leonard Wood Park (Table 5.2).

The improvements in water quality in the lower reaches of the river coincide with the removal of a significant point-source discharge; up until November 2001, treated municipal wastewater from Wainuiomata was discharged into the river 0.3 km downstream of Leonard Wood Park. The pre- and post-removal effects of the discharge on water quality in the lower river have been documented previously (e.g., Hutt City Council 1998, Wellington Regional Council 2002, de Silva 2004) and are clearly illustrated by the dramatic decreasing trends in dissolved reactive phosphorus concentrations over the reporting period (Figures 5.5-5.6).

Table 5.2: Trend slopes (units per year) for selected raw and flow-adjusted water quality variables monitored at the four RSoE sites on the Wainuiomata River over 1 September 1997 to 31 August 2003 inclusive. Trends shown in boxes shaded green with bold type are statistically significant to ***p***<0.05, while trends shown in boxes shaded yellow or orange are significant to p<0.10 and p<0.20 respectively. A trend slope preceded by a "-" sign denotes a decreasing trend.

Variable	Trend slope (SSSKE) for raw and flow-adjusted (FA) data						
	Manuka Track		L. Wood Park		Golf Course		White Br.
	Raw	FA	Raw	FA	Raw	FA	Raw
Dissolved Oxygen (% sat.)	0.760	0.804	1.66	1.95	2.89	3.19	0.700
pH	0	0.009	0	0.017	0.047	0.045	0
Conductivity (uS/cm)	1.43	1.01	0.483	0.412	-2.55	-3.20	-0.599
Visual Clarity (m)	0.082	0.059	0.056	0.040	0.094	0.078	0.088
Turbidity (NTU)	-0.085	-0.070	0.040	0.001	0	0.003	-0.161
Faecal coliforms	-1.75	-2.02	-27.3	-33.4	-62.5	-60.5	-39.0
Nitrate Nitrogen (mg/L)	-0.005	-0.005	-0.013	-0.020	-0.196	-0.216	-0.075
Ammoniacal Nitrogen (mg/L)	0*	0*	0*	<-0.001*	-0.025	-0.026	0*
Total Nitrogen (mg/L)	0.020	0.023	-0.041	-0.036	-0.229	-0.135	-0.252
Diss. R. Phosphorus (mg/L)	0*	<-0.001*	0*	<-0.001*	-0.046	-0.054	-0.013
Total Phosphorus (mg/L)	-0.004	-0.004	-0.006	-0.004	-0.027	-0.017	-0.022

* Trend affected by large numbers of non-detect values

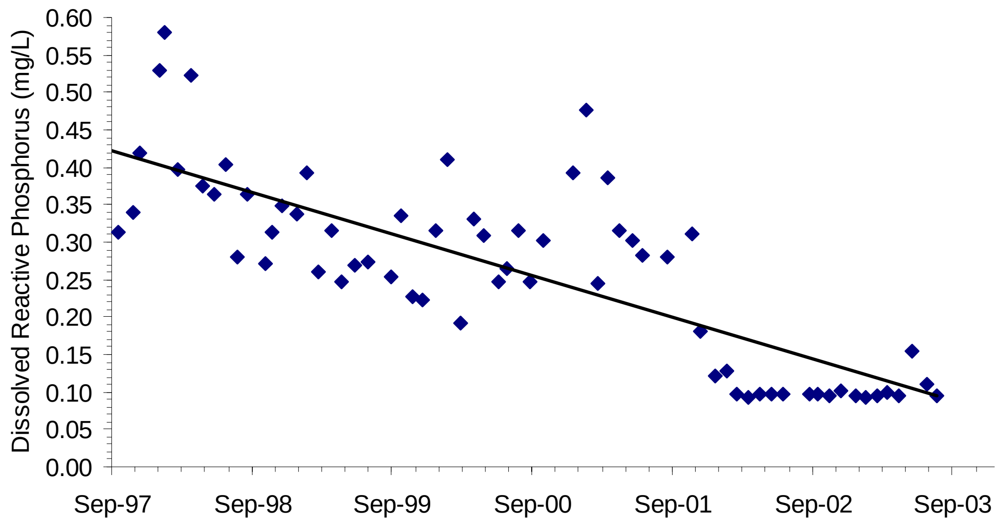


Figure 5.5: Dissolved reactive phosphorus concentrations (flow-adjusted data) recorded in the Wainuiomata River opposite the Wainuiomata Golf Course over 1 September 1997 to 31 August 2003 inclusive. The solid black line shows the overall trend in the data record.

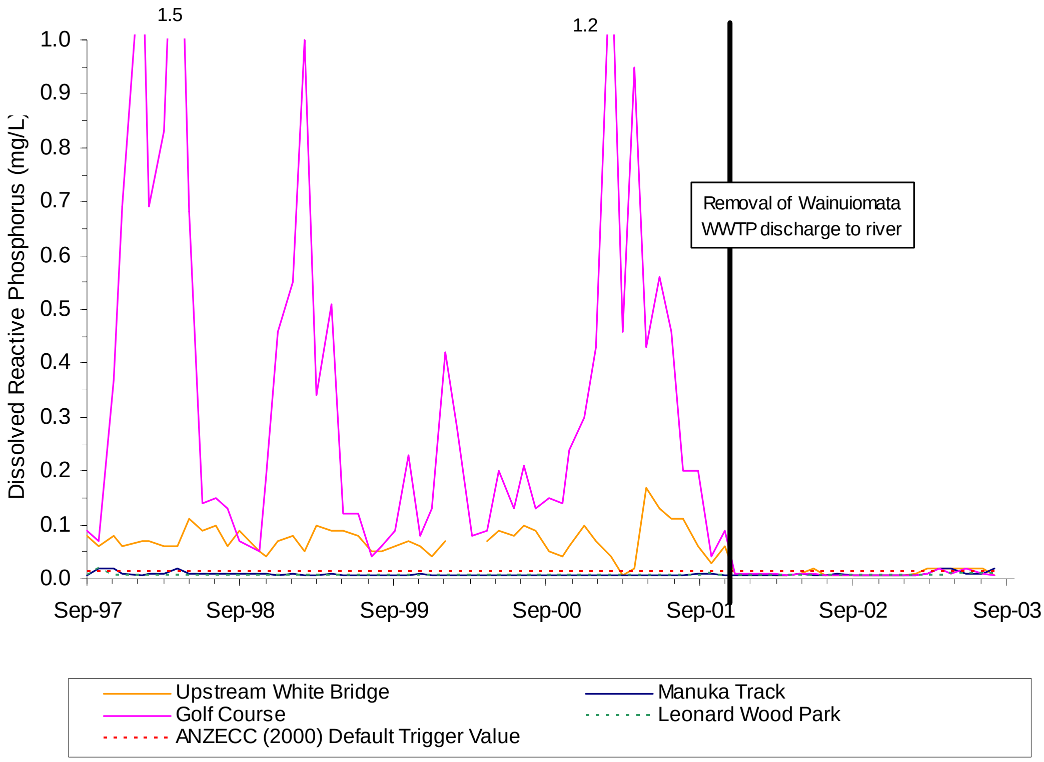


Figure 5.6: Dissolved reactive phosphorus concentrations (non flow-adjusted data) recorded at RSoE sites on the Wainuiomata River over 1 September 1997 to 31 August 2003 inclusive.

5.2.6 Ruamahanga River

Of the five RSoE sites monitored on the Ruamahanga River over 1 September 1997 to 31 August 2003 inclusive, no statistically significant trends were evident in the raw water quality records for any of the sites. The only exception was dissolved reactive phosphorus at the upstream site at Mount Bruce. Dissolved phosphorus concentrations at this site decreased by -0.0002 mg/L per year. A similar decrease was also observed in flow-adjusted data from this site (-0.0003 mg/L per year).

Scarsbrook et al. (unpublished data) analysed trends in water quality at three sites on the Ruamahanga River over 1989-2003; State Highway 2 (approximately 2 km upstream of Site FB37 at Mount Bruce), Wardells (approximately 9.5 km upstream of Site FB39 at Gladstone) and Waihenga (at Site FB40). The following statistically significant ($p<0.01$) trends were identified:

- Small decreases in ammoniacal nitrogen concentrations at State Highway 2 and Wardells in both the raw and flow-adjusted data sets (-0.000295 and -0.000545 mg/L per year respectively, flow-adjusted data), consistent with national trends.
- A small increase in flow adjusted total nitrogen concentrations at State Highway 2 (-0.000933 mg/L per year).

- Increases in clarity at all three sites in both the raw and flow-adjusted data sets. The flow-adjusted increases were 0.0.096 m/ year (State Highway 2), 0.031 m/year (Wardells) and 0.018 m/year (Waihenga).
- A small decrease in pH (0.001 units per year) at Waihenga.
- Increases in both raw and flow-adjusted dissolved reactive phosphorus concentrations at Wardells and Waihenga (0.0002 and 0.0003 mg/L per year respectively, flow-adjusted data).

5.2.7 Urban streams

Several streams in Wellington City recorded significant decreases in nitrate nitrogen concentrations over the reporting period. These include the Karori Stream at Makara Peak (-0.104 mg/L per year) (Figure 5.7) and Owhiro Stream at Mouth (-0.104 mg/L per year). The Kaiwharawhara Stream at Ngaio Gorge recorded a significant decrease in total nitrogen concentrations over this same period (-1.795 mg/L per year). The reason for these trends are unclear but may be related to various Wellington City Council initiatives (e.g., Sewage Pollution Elimination Project 1993, Lateral Policy 1993) which, over the course of the last 10 or so years, have significantly reduced the extent and frequency of sewage leaks into watercourses and the sea in Wellington City. However, if this was the case, significant decreases might be expected in other variables, notably BOD_5, ammoniacal nitrogen and dissolved reactive phosphorus. No such decreases were observed for the Karori[7], Owhiro or Kaiwharawhara Streams, although detection limits for ammoniacal nitrogen and dissolved reactive phosphorus were possibly too coarse (0.05 mg/L and 0.01 mg/L respectively) to detect significant changes in concentrations over the reporting period (Appendix 8).

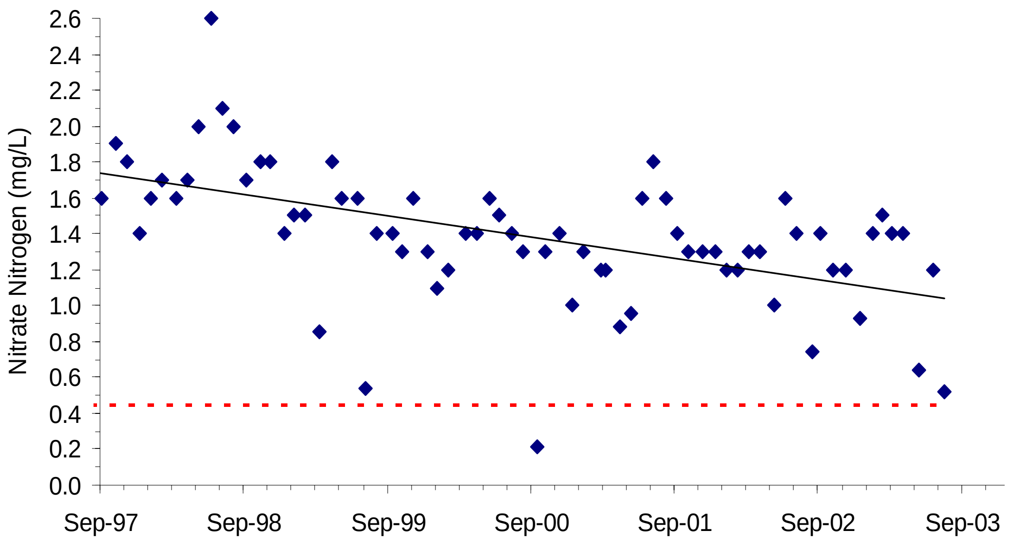


Figure 5.7: Nitrate nitrogen concentrations (non flow-adjusted data) recorded in the Karori Stream at Makara Peak over 1 September 1997 to 31 August 2003 inclusive. The solid black line shows the overall trend in the data record and the red dashed line indicates the ANZECC (2000) lowland trigger value.

[7] In fact total phosphorus concentrations increased in the Karori Stream at Makara Peak over the reporting period (0.014 mg/L per year).

Porirua Stream showed a significant decreasing trend in faecal coliform counts over 1 September 1997 to 31 August 2003 (raw data). At the monitoring site in the upper reaches at the Glenside Overhead Cables, faecal counts decreased by 132.9 cfu/100 mL per year while counts further downstream at Wall Park decreased by 128.7 cfu/100 mL per year. Total nitrogen concentrations at Wall Park also showed a significant decreasing trend (-0.496 mg/L per year). While these reductions may represent improvements in water quality, the level of faecal contamination in Porirua Stream remains above recommended guidelines; the median faecal coliform and *E. coli* counts at Wall Park over 1 January 2003 to 31 December 2004 inclusive were 940 and 710 cfu/100 mL respectively.

Raw data for the Waiwhetu Stream at Wainuiomata Hill showed a significant decreasing trend in ammoniacal nitrogen concentrations over the reporting period (-0.005 mg/L). However this trend was not statistically significant in the flow-adjusted record.

Based on raw data, a deterioration in water quality was observed in two urban streams:

- The lower reaches of the Ngauranga Stream (Wellington City) exhibited significant increases in the concentrations of dissolved reactive phosphorus (0.007 mg/L per year), total phosphorus (0.044 mg/L per year) and faecal coliforms (223.7 cfu/100 mL per year) over the reporting period. A statistically significant decreasing trend in pH was also observed (-0.020 pH units per year). The reason for the apparent deterioration in water quality in unclear. The Wellington City Council completed a sewerage-stormwater cross-connection study in 2003 but continues to report very high faecal bacteria counts in Ngauranga Stream (Capacity 2005).
- The Mazengarb Drain (Kapiti Coast) exhibited significant increases in dissolved reactive phosphorus (0.085 mg/L per year), total phosphorus (1.14 mg/L per year), nitrate nitrogen (0.259 mg/L per year) (Figure 5.8), and total nitrogen (1.36 mg/L per year) concentrations. While these increases are large, Table 4.5 (refer Section 4.3) shows that nutrient concentrations are already very high in the drain (e.g., the median total nitrogen concentration over July 1997 to July 2003 inclusive was 4.39 mg/L). The reason for the apparent deterioration in water quality is not clear but may be related to changes in the performance of the Paraparaumu WWTP. The Paraparaumu WWTP discharges treated municipal wastewater into the Mazengarb Drain upstream of the RSoE sampling site and was upgraded during the reporting period in preparation of receiving an additional input of wastewater from Waikanae. The treatment upgrade was successful in reducing spikes in ammoniacal nitrogen concentrations in the discharge but phosphorus removal is now significantly lower than prior to the upgrade (Anne Robertson[8], pers. comm.).

[8] Laboratory Manager, Kapiti Coast District Council

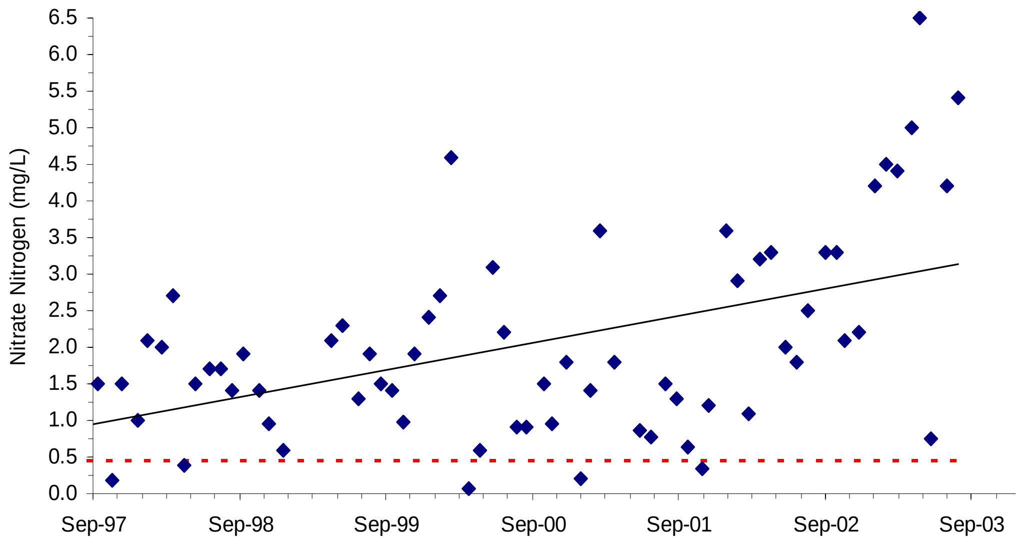


Figure 5.8: Nitrate nitrogen concentrations (non flow-adjusted data) recorded in the Mazengarb Drain above the Waikanae River over 1 September 1997 to 31 August 2003 inclusive. The solid black line shows the overall trend in the data record and the red dashed line indicates the ANZECC (2000) lowland trigger value.

5.3 Macroinvertebrates

Analysis of macroinvertebrate community health by Death and Death (2005) concluded that this remained relatively stable at most RSoE sites over the last five years (Appendix 7). However, statistically significant ($p<0.1$) improvements were observed at a few sites. These include the Pauatahanui Stream at Elmwood Bridge (Figure 5.9), the Hutt River opposite Manor Park Golf Course (Figure 5.10), the Whangaehu River upstream of its confluence with the Ruamahanga River (Figure 5.11), and the Wainuiomata River at both Leonard Wood Park and the Wainuiomata Golf Course (Figures 5.12). The improvement in macroinvertebrate health in the lower Wainuiomata River (Wainuiomata Golf Course) coincides with improvements in physico-chemical water quality with the removal of the Wainuiomata WWTP discharge in late 2001 (refer Section 5.2.5). The reasons for the other reported improvements are not clear. Several sites showed a decline in macroinvertebrate health (e.g., Hutt River at Birchville, Mangaroa River at Kalcoolies Corner), although this was only evident in two of the four macroinvertebrate indices.

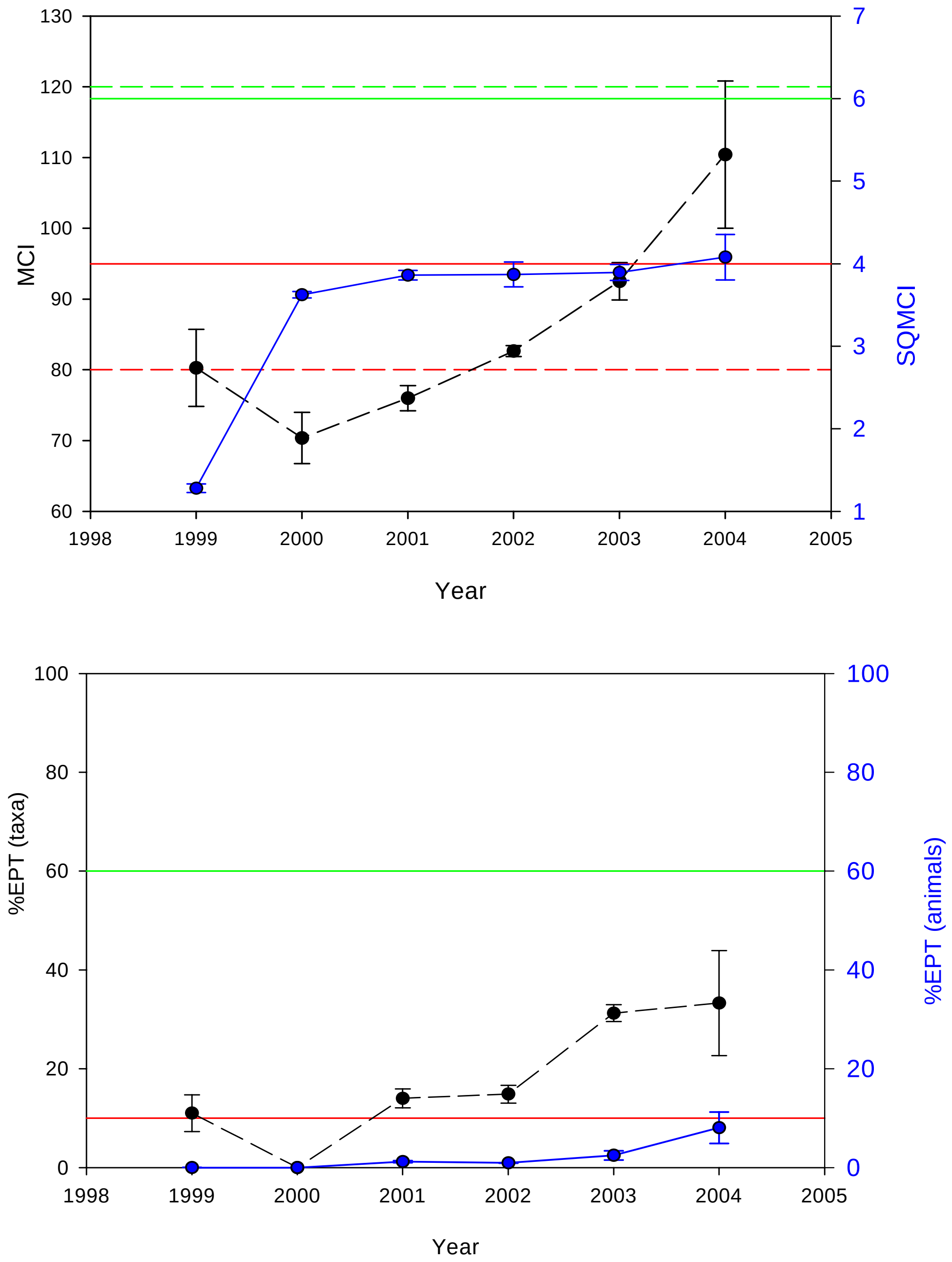


Figure 5.9: Pauatahanui Stream at Elmwood Bridge – plots of mean (± 1 SE) MCI (- -), SQMCI (----), % EPT (taxa) (- - -), and % EPT (individuals) (----) scores, based on annual monitoring over 1999 to 2004 inclusive. Thresholds indicative of low water quality sites are plotted in red and those of high water quality in green with either dashed or solid lines corresponding to the appropriate index. Note that the threshold lines may overlap depending on the scale used. Statistically significant (***p***=0.1) increasing trends were detected in all four macroinvertebrate indices.

(Source: adapted from Death and Death 2005).

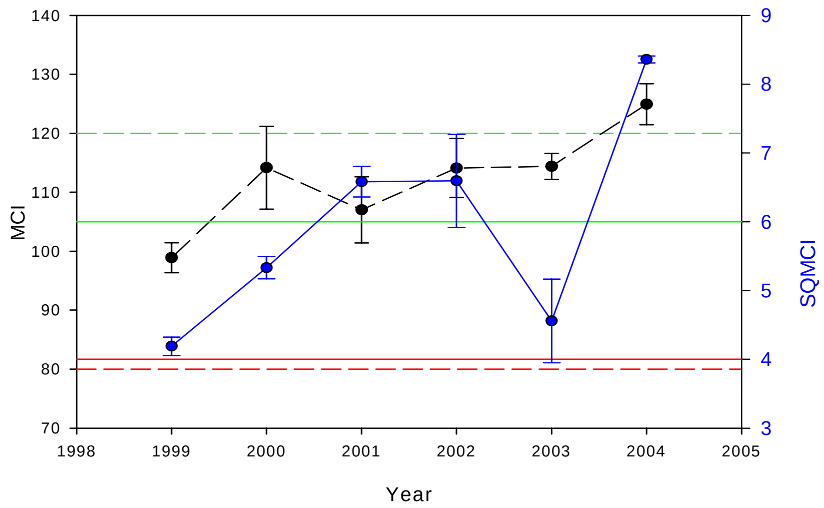


Figure 5.10: Hutt River opposite Manor Park Golf Club – plot of mean (± 1 SE) MCI (- - -) and SQMCI (----) scores, based on annual monitoring over 1999 to 2004 inclusive. Thresholds indicative of low water quality sites are plotted in red and those of high water quality in green with either dashed or solid lines corresponding to the appropriate index. Note that the threshold lines may overlap depending on the scale used. Statistically significant (p=0.1) increasing trends were identified in the mean MCI scores (and %EPT taxa scores - not shown).

(Source: adapted from Death and Death 2005).

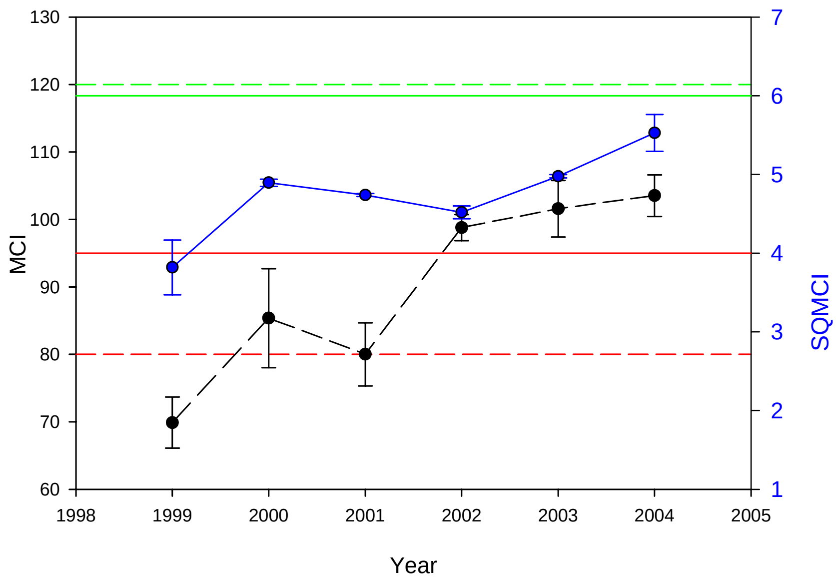
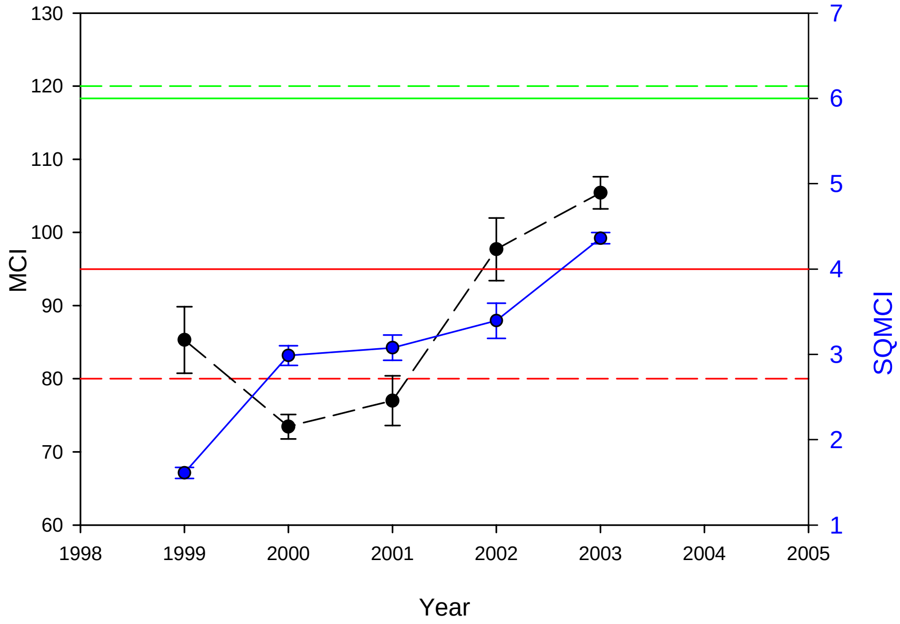


Figure 5.11: Whangaehu River upstream of its confluence with the Ruamahanga River – plot of mean (± 1 SE) MCI (- - -) and SQMCI (----) scores for the, based on annual monitoring over 1999 to 2004 inclusive. Thresholds indicative of low water quality sites are plotted in red and those of high water quality in green with either dashed or solid lines corresponding to the appropriate index. Note that the threshold lines may overlap depending on the scale used. Statistically significant (***p***=0.1) increasing trends were observed in both indices.

(Source: adapted from Death and Death 2005).



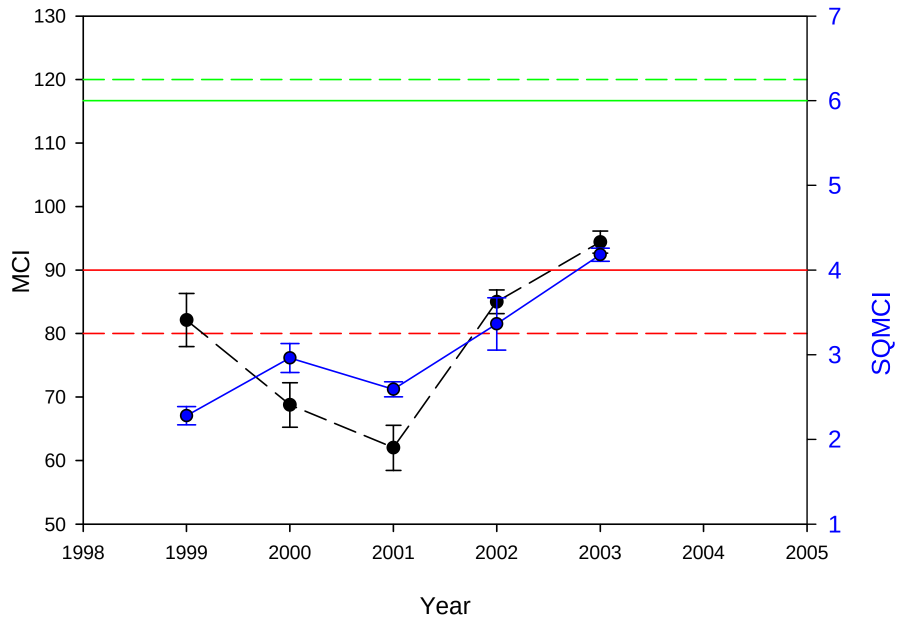


Figure 5.12: Plots of mean (± 1 SE) MCI (- - -) and SQMCI (----) scores for the Wainuiomata at Leonard Wood Park (top) and the Wainuiomata Golf Course (bottom), based on annual monitoring over 1999 to 2003 inclusive. Thresholds indicative of low water quality sites are plotted in red and those of high water quality in green with either dashed or solid lines corresponding to the appropriate index. Statistically significant (p=0.1) increasing trends were identified in the mean SQMCI scores at both sites, and mean % EPT (taxa) and % EPT (individuals) scores (not shown) at Leonard Wood Park and the Wainuiomata Golf Course respectively.

(Source: adapted from Death and Death 2005).

5.4 Synthesis

Significant temporal trends in water quality were only apparent at a small number of the 51 RSoE sites and, in most cases, were only seen in one or two water quality variables. It is difficult to explain many of the observed trends, largely because flow-adjusted records were only available for 14 sites (i.e., flow effects can not be ruled out as being a contributing factor to the majority of observed trends). However, several sites did exhibit a marked improvement in water quality over the 1 September 1997 to 31 August 2003 reporting period that can not be attributed to flow effects. These sites were largely confined to lowland rivers or streams influenced by agricultural or municipal wastewater discharges that had ceased during the reporting period. These include the lower reaches of the Waitohu Stream, Mangaone Stream, Ngarara Stream, and the Wainuiomata River.

Coarse detection limits used in the analysis of some water quality variables at sites in the western Wellington region (e.g., ammoniacal nitrogen, dissolved reactive phosphorus) may also have limited the ability to detect some changes in water quality over the reporting period. Lower detection limits, and standardisation of laboratory analytical methods since August 2003 should help improve future analysis and reporting of temporal trends at RSoE sites across the Wellington region.

6. Discussion

Policy 5.2.6 of the Regional Freshwater Plan (RFP) requires *all* rivers and streams across the Wellington region to be managed for aquatic ecosystem health. In addition to this minimum requirement, the Regional Policy Statement (RPS) and RFP require a number of reaches on rivers and streams to be managed for other specified purposes, including natural state, fisheries and fish spawning, or enhancement for aquatic ecosystem health, contact recreation or fish habitat. This section focuses on whether these management objectives are being achieved by assessing the findings of the spatial and temporal trend assessments presented in Sections 4 and 5. Other reaches of rivers and streams not listed in the RPS or RFP exhibiting poor water quality are also discussed, together with actions initiated or required to address poor water sites. Some key limitations of the RSoE monitoring programme are also outlined.

6.1 RPS and RFP management requirements

RSoE sites located on reaches of waterbodies managed for natural state, fisheries and fish spawning, or enhancement purposes (aquatic ecosystem health or fish habitat and spawning) are shown in Figure 6.1. River or stream reaches that are to be enhanced for contact recreation purposes are not shown or discussed here. The RSoE monitoring programme does not specifically address recreational water quality and *E. coli*, the preferred microbiological indicator for freshwater recreational waters, was not monitored for the majority of the reporting period.

6.1.1 Natural state

Five of the 51 RSoE sites monitored over the 1997-2003 reporting period are located on river or stream reaches listed in Policy 5.2.1 of the RFP requiring water quality to be managed in its natural state. These monitoring sites and their associated water quality and macroinvertebrate health grades are summarised in Table 6.1.

Table 6.1: WQI and macroinvertebrate health grades for RSoE sites located on river and stream reaches where water quality is to be managed in its natural state, based on selected data from Tables 4.6 and 4.8 in Section 4.

Site No.	Site Name	WQI Grade & Site Ranking (51 sites)	Macroinvertebrate health ranking based on mean scores across all 4 biotic indices (42 sites)	MCI Grade	SQMCI Grade
FB01	Waitohu S at Water Supply Intake	Very Good (5)	1	Very Good	Very Good
FB03	Otaki R at Pukehinau	Very Good (2)	7	Very Good	Very Good
FB31	Wainuiomata R at Manuka Track	Very Good (7)	2	Very Good	Very Good
FB35	Orongorongo R at Orongo. Stn	Very Good (6)	14	Very Good	Very Good
FB47	Waiohine R at Gorge	Very Good (1)	5	Very Good	Very Good

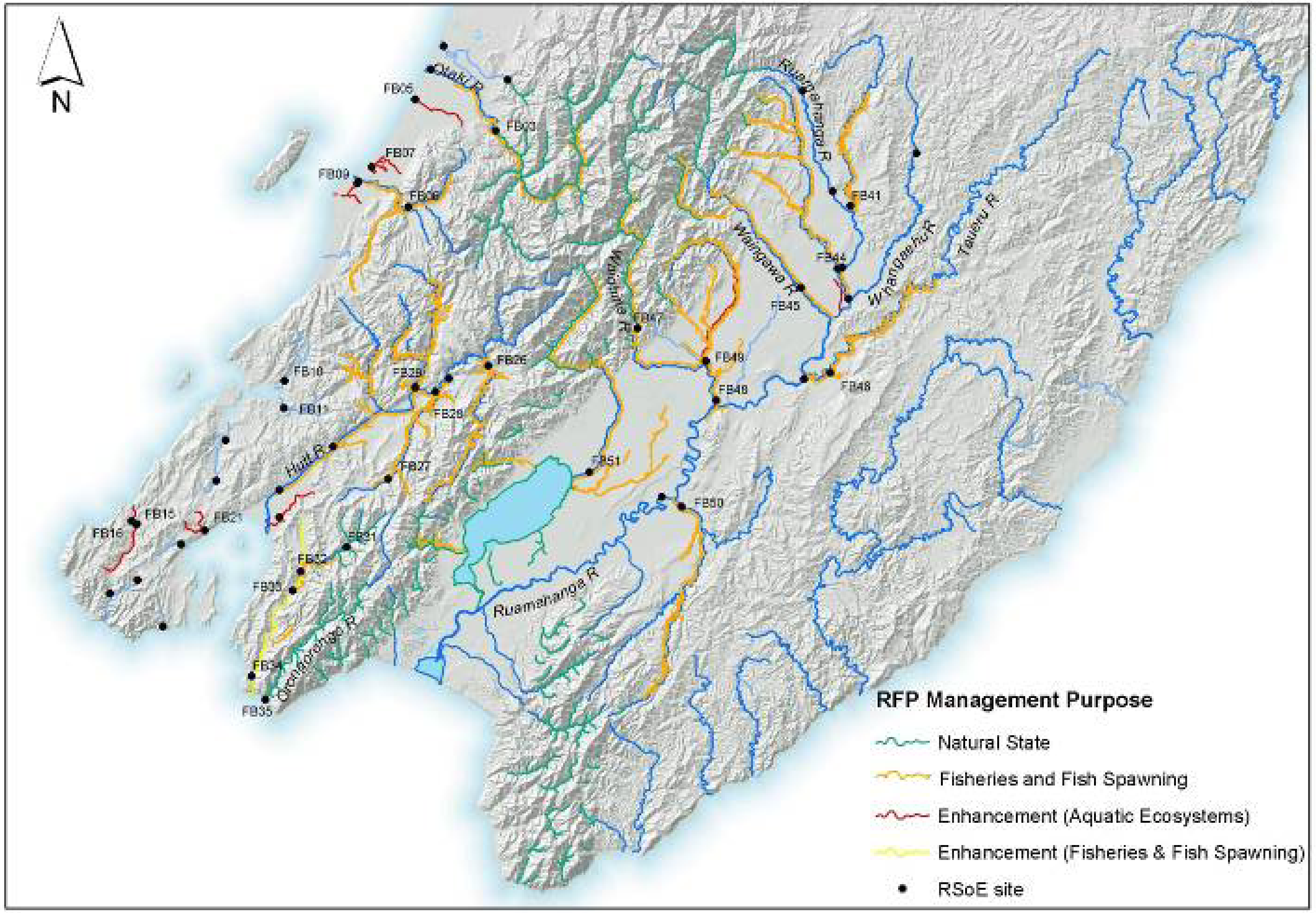


Figure 6.1: RSoE sites and river and stream reaches managed for natural state, fisheries or fish spawning and enhancement, in accordance with the Regional Freshwater Plan.

Note: Policy 5.2.6 of the RFP requires all rivers and streams to be managed for aquatic ecosystem health as a minimum.

All five sites have very good water quality and macroinvertebrate communities, with four ranked well inside the top 10 RSoE sites for each. This reflects the fact that these sites are located on cool wet, high elevation river and stream reaches associated with the Tararua, Rimutaka and Aorangi Ranges (refer Section 4.3.14). As a result, all have their upstream catchments in unmodified indigenous forest cover. Not surprising, no significant deterioration in water quality at these sites was identified over the reporting period.

6.1.2 Fisheries and fish spawning

Eighteen RSoE sites monitored over the reporting period are on river or stream reaches listed in Policy 5.2.3 of the RFP as areas where water quality is to be managed for trout fisheries and spawning. These monitoring sites are listed in Table 6.2, together with their associated water quality and macroinvertebrate health grades and summary details of selected variables considered influential to trout populations; ammoniacal nitrogen concentrations, water temperature and periphyton cover. Habitat quality is also very important but this was not assessed during the reporting period.

The majority (13) of the 18 sites had good or very good water quality, based on the WQI. In all cases, the variable differentiating the WQI grade was faecal coliforms; the *median* faecal coliform count at the "good" sites failed to comply with the guideline value during the reporting period. Generally, sites with good or very good water quality also recorded similar grades for macroinvertebrate health. One obvious exception is the Wainuiomata River at Leonard Wood Park. Disagreements between physico-chemical water quality and macroinvertebrate health assessments have been reported previously for this site (e.g., Stansfield 2000, Warr 2001), suggesting that the instream macroinvertebrate community may be affected more strongly by another variable not encompassed within the WQI or some other factor (e.g., habitat quality). The site at Leonard Wood Park is located just downstream of the Wainuiomata urban area and may be impacted by stormwater discharges. This site, together with lower sites on the Wainuiomata River, are also likely to be affected by water abstraction; river flows at Leonard Wood Park have dropped below the RFP minimum requirements in most years over 1999-2004 inclusive (Watts 2005).

The remaining five sites had WQI grades of fair or poor, and fair or poor macroinvertebrate health grades. These are:

- Taueru River at Gladstone (fair water quality)
- Mangaroa River at Kalcoolies Corner (fair water quality) and Te Marua (poor water quality)
- Kopuaranga Stream at Stewarts (poor water quality)
- Wainuiomata River at Wainuiomata Golf Course (poor water quality)

These five sites recorded a significantly greater number of exceedances of guidelines, including guidelines for ammoniacal nitrogen (Table 6.2) and other dissolved nutrients. In addition, the Kopuaranga Stream and Taueru River often exceeded guidelines for filamentous periphyton cover (35.7 % and 17.4 %

Table 6.2: WQI and macroinvertebrate health grades for RSoE sites located on river and stream reaches where water quality is to be managed for trout fishery and spawning, based on selected data from Tables 4.5-4.8 in Section 4.

Site No.	Site Name	Temperature		Ammoniacal Nitrogen (% Results >0.025 mg/L)	Filamentous Periphyton Cover (% Results >30%)	WQI Grade	MCI Grade	SQMCI Grade
		Max (˚C)	% Results >20 ºC					
FB03	Otaki R at Pukehinau	18.1	0	0	No data	Very Good	Very Good	Very Good
FB06	Waikanae R at Reikorangi Br	17.5	0	1.4	No data	Good	Very Good	Very Good
FB23	Hutt R at Birchville Canoe Club	19.2	0	5.5	No data	Good	Very Good	Very Good
FB24	Hutt R opp. Manor Park G.C.	21.1	6.8	0	No data	Good	Good	Good
FB25	Hutt R u/s of Melling Br	21.7	5.5	1.4	No data	Good	Good	Good
FB26	Pakuratahi R 50m d/s Farm Ck	20.0	0	0	No data	Very Good	Very Good	Very Good
FB27	Mangaroa R at Kalcoolies Cnr	19.0	0	9.6	No data	Fair	Fair	Poor
FB28	Mangaroa R at Te Marua	19.6	0	67.1	No data	Poor	Fair	Fair
FB29	Akatarawa R u/s Hutt R confl.	19.8	0	45.2	No data	Very Good	Very Good	Very Good
FB32	Wainuiomata R at L. Wood Pk	19.0	0	1.4	No data	Good	Fair	Poor
FB33	Wainuiomata R at Golf Course	19.6	0	63.0	No data	Poor	Poor	Poor
FB41	Kopuaranga S at Stewarts	18.7	0	16.4	35.7	Poor	Good	Fair
FB44	Waipoua R at Colombo Rd Br	21.8	2.7	0	7.0	Good	Good	Fair
FB45	Waingawa R at South Rd	24.3	8.1	0	0	Very Good	Good	Very Good
FB46	Taueru R at Gladstone	21.4	4.1	45.9	17.4	Fair	No data	No data
FB47	Waiohine R at Gorge	18.6	0	0	2.8	Very Good	Very Good	Very Good
FB50	Huangarua R at Ponatahi Br	23.9	8.1	1.4	30.6	Very Good	Good	Good
FB51	Tauherenikau R at Websters	23.5	11.1	0	5.6	Very Good	Good	Good

of sampling occasions respectively). As discussed in Section 4.4.1, these waterbodies are affected by low base-flows, exacerbated by upstream water abstraction. Although data on filamentous periphyton cover was not available for the monitoring sites on the lower reaches of the Mangaroa and Wainuiomata Rivers during the reporting period, elevated periphyton cover has been reported previously (e.g., de Silva 2004) and is likely given the very high dissolved nutrient concentrations in these rivers and, in the case of the lower Wainuiomata River, frequent low flows as a result of significant upstream water abstraction. Water quality in the lower Mangaroa and Wainuiomata Rivers is discussed further in Sections 6.1.3 and 6.1.4.

Water temperature was not one of the six water quality variables encompassed within the WQI but is very influential on trout populations. Quinn and Hickey (1990) reported that water temperatures above 20 ˚C may adversely affect some sensitive macroinvertebrate species consumed by trout (e.g., mayflies, stoneflies) and temperatures above 25 ˚C may adversely affect fish spawning. Based on the results of monthly measurements of temperature undertaken at RSoE sites, eight of the 18 sites located on river and stream reaches managed for trout fishery values reached 20 ˚C on at least one occasion over the reporting period. The Tauherenikau at Websters exceeded this temperature on 11.1 % of sampling occasions, recording a maximum temperature of 23.5 ˚C. The Waingawa River at South Road and Huangarua River at Ponatahi Bridge recorded the highest maximum temperatures (24.3 ˚C and 23.9 ˚C respectively), although raw data for the latter site showed a significant decreasing trend in temperature over the reporting period (-0.308 ˚C per year).

The water temperature records collected under the RSoE programme provide a conservative picture of the potential extreme elevated temperatures trout and other instream fauna may experience. Measurements are taken only monthly, and at approximately the same time each month (generally in the morning). *Continuous* temperature monitoring provides a better indicator of the likely impacts on instream fauna because water temperature exhibits large diurnal fluctuations, with warmer and more harmful temperatures generally recorded in the afternoon. Continuous temperature monitoring has been in place for a few years at limited sites in the region. Results to date confirm that in some river and stream reaches, instream fauna can be subjected to very warm water temperatures for a considerable period of time during summer low flows (Figure 6.2). Elevated water temperatures are particularly common in rivers and streams in the eastern Wairarapa and reflect lower rainfall and therefore lower base flows. In many cases, a lack of riparian shade and upstream water abstraction further increase water temperatures.

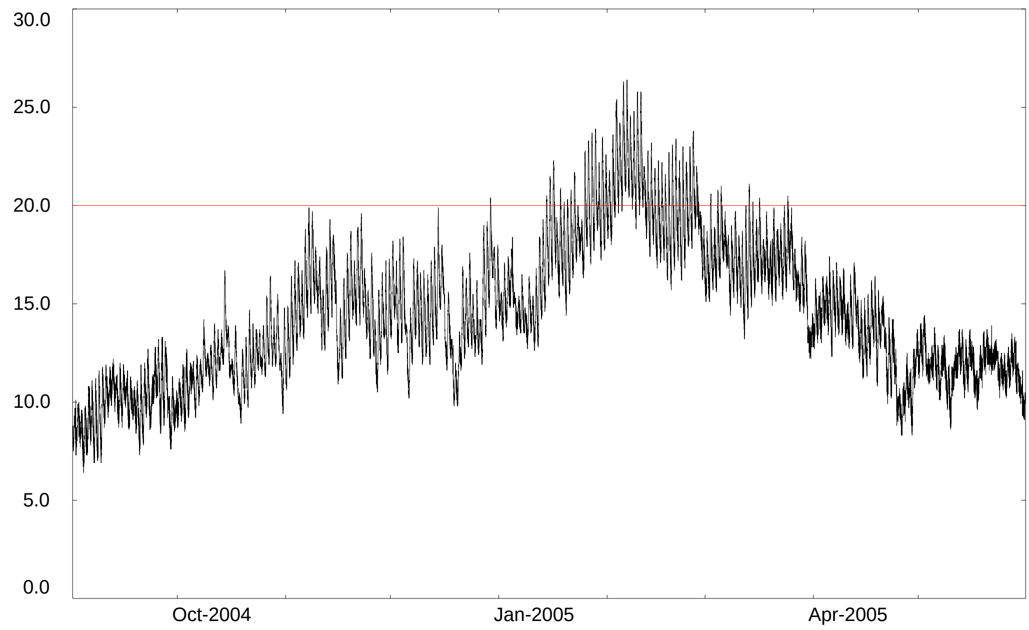


Figure 6.2: Continuous water temperature records for the Hutt River at Taita Gorge (downstream of Site FB24), 1 September 2004 to 31 May 2005 inclusive.

6.1.3 Rivers with water quality requiring enhancement

Eleven of the 51 RSoE sites monitored over the 1997-2003 reporting period are located on river or stream reaches listed in Method 25 of the RPS and/or Policy 5.29 of the RFP as areas where water quality is to be enhanced to satisfy aquatic ecosystem or fishery/fish spawning purposes. The state of water quality and macroinvertebrate health at these sites is summarised in Table 6.3, together with any trends observed over the reporting period.

(a) Mangaone Stream

Water quality in the Mangaone Stream at Sims Road Bridge received a WQI grade of poor. However, significant increasing trends in visual clarity and decreasing trends in the concentrations of turbidity, BOD_5, turbidity, total organic carbon, ammoniacal nitrogen and faecal coliforms were identified over the reporting period (refer Section 5.2.2). These trends represent an improvement in water quality and are attributed to the removal of point source dairy shed effluent discharges.

(b) Ngarara Stream

Water quality in the Ngarara Stream at Field Way has been poor for many years, not helped by the nature of the stream catchment (low-gradient, peaty soils). However, significant decreasing trends were evident in the concentrations of total organic carbon, nutrients and faecal coliforms over the reporting period (refer Section 5.2.3). These trends represent an improvement in water quality and coincide with the removal of treated municipal wastewater from the stream in early 2002.

Table 6.3: WQI and macroinvertebrate health grades for RSoE sites located on river and stream reaches where water quality is to be enhanced, based on selected data from Tables 4.5, 4.6 and 4.8 in Section 4. Compliance with guideline values is determined using the median value from monthly monitoring undertaken over July 1997 to July 2003 inclusive. Overall trends in water quality over the reporting period are also presented.

Site No.	Site Name	WQI Grade & Site Ranking (51 sites)	Guideline Compliance (Median Values)						Water Quality Trend	MCI Grade	SQMCI Grade	Macroinvertebrate Trend (Death & Death 2005)
			DO	Clarity	FC	NO_3-N	Amm. N	DRP				
Management Purpose: Enhancement for aquatic ecosystem health												
FB05	Mangaone S at Sims Rd Br	Poor (47)	×	×	×	✓	×	✓	Improving	No Data	No Data	No Data
FB07	Ngarara S at Field Way	Poor (50)	×	×	×	×	×	×	Improving	No Data	No Data	No Data
FB09	Mazengarb Drn u/s Waikanae R	Poor (51)	×	×	×	×	×	×	Declining	No Data	No Data	No Data
FB15	Makara S u/s Ohariu Stream	Good (24)	✓	✓	×	✓	✓	✓	No Change	No Data	No Data	No Data
FB16	Makara S at Kennels	Fair (29)	✓	×	×	✓	✓	✓	Improving	Fair	Fair	No Change
FB20	Kaiwharawhara S at Ngaio Gorge	Fair (36)	✓	✓	×	×	✓	×	No Change	Fair	Poor	No Change
FB21	Ngauranga S 400m u/s Mouth	Poor (48)	✓	✓	×	×	×	×	Declining	Poor	Poor	Unclear
FB30	Waiwhetu S at Wainui Hill Br	Poor (49)	×	×	×	×	×	✓	No Change	No Data	No Data	No Data
FB49	Mangatarere R at SH2	Poor (44)	✓	✓	×	×	×	×	No Change	Fair	Fair	No Change
Management Purpose: Enhancement for trout fishery and spawning												
FB32	Wainuiomata R at L. Wood Pk	Good (18)	✓	✓	×	✓	✓	✓	Improving	Fair	Poor	Improving
FB33	Wainuiomata R at Golf Course	Poor (42)	✓	✓	×	×	×	×	Improving	Poor	Poor	Improving
FB34	Wainuiomata R u/s of White Br	Poor (40)	✓	×	×	×	✓	×	Improving	Poor	Poor	No Change

Further improvements in water quality may become evident in the future as a result of a riparian rehabilitation pilot programme initiated on the lower reaches of the Kakariki Stream in 2001. The Kakariki Stream is a major tributary of the Ngarara Stream and drains a catchment area of approximately 1,786 ha. Results of water quality monitoring on this tributary to date reveal marked improvements in bank stability and decreased water temperatures (Warr 2004).

(c) Mazengarb Drain

Water quality in the lower reaches of the Mazengarb Drain received a WQI grade of poor and appears to have declined over the reporting period. This is evidenced by significant increasing trends in dissolved and total nutrient concentrations (refer Section 5.2.7). The Mazengarb Drain receives municipal wastewater from the Paraparaumu WWTP, agricultural and stormwater runoff, and inputs from bird life (e.g., Ratanui Lakes, Lake Mazengarb). Low flows in the drain, together with a very low catchment gradient, prevent significant dilution of these discharges and attenuation of their effects.

(d) Makara Stream

The Makara Stream below its confluence with Ohariu Stream and at the Kennels has good water quality relative to other waterbodies listed in the RFP as requiring enhancement. However, both sites did exceed nutrient and microbiological water quality guidelines on a number of occasions over the reporting period, with the greatest number of exceedances occurring at the Kennels.

Temporal trend analyses suggest water quality at this site may be improving; small yet statistically significant increasing trends in visual clarity (0.092 m per year) were observed over the reporting period (raw data), together with significant decreasing trends in faecal coliforms (-134.8 cfu/100 mL per year). No change was evident in macroinvertebrate health over the reporting period. Agricultural practices and possibly discharges from suspect septic tanks probably impact on water quality in Makara Stream.

(e) Kaiwharawhara Stream

Water quality in the Kaiwharawhara Stream at Ngaio Gorge received a WQI grade of fair. This site regularly exceeded nutrient and microbiological water quality guidelines, although had better water quality and macroinvertebrate health than some other urban streams in Wellington City.

No improvements in water quality or macroinvertebrate health were observed over the reporting period other than a significant decreasing trend in total nitrogen concentrations.

(f) Ngauranga Stream

The lower reaches of the Ngauranga Stream have amongst the poorest water quality of the 51 RSoE sites monitored over the reporting period. With the exception of ammoniacal nitrogen, nutrient concentrations and faecal bacteria counts exceeded guideline values on over 95 % of sampling occasions. Water clarity was also poor, exceeding the MfE (1994) guideline on over 90 % of sampling occasions. Temporal trend analyses suggest that water quality declined over the reporting period; significant increasing trends were evident in dissolved and total phosphorus concentrations and faecal bacteria counts (raw data, refer Section 5.2.7). Macroinvertebrate health is also extremely poor in the Ngauranga Stream and may also have declined, although the trend is unclear. Death and Death (2005) reported significant decreases in EPT indices (both EPT taxa and animals) over 1999-2003 inclusive. In contrast, no significant change was evident in MCI scores, while SQMCI scores improved. Poor macroinvertebrate health probably reflects both poor physico-chemical water quality and instream habitat; the lower reaches of the Ngauranga Stream are channelised and have a concrete bottom.

The Ngauranga Stream receives contaminants from several sources including industrial and urban stormwater inputs, and has an ongoing history of pollution incidents (see Figure 6.8). Sewer cross-connections existed in the Tyers Stream catchment in the past (and some may still exist in this or other parts of the Ngauranga Stream catchment), along with leachate discharges from the closed Raroa Park Landfill. Leachate from this landfill was diverted to sewer a few years ago, although occasional overflows to surface water have been reported since the diversion (Figure 6.3).

Figure 6.3: Leachate spill from the closed Raroa Park Landfill.

(g) Waiwhetu Stream

The Waiwhetu Stream has very poor water quality and has not shown any real improvement over the reporting period. Dissolved oxygen, visual clarity, nutrient and faecal bacteria guidelines were exceeded on most sampling occasions, with faecal coliform counts exceeding 100 cfu/100 mL and 1,000 cfu/100 mL on 97.3% and 63% of sampling occasions respectively.

The Waiwhetu Stream has a well documented history of contamination, especially sediment contamination (e.g., Deely et al. 1992). This includes high concentrations of lead and zinc. Sewer overflows also occur at times (refer Section 4.3.14) and the stream receives multiple stormwater discharges from the surrounding urban area. Greater Wellington is currently working with the Hutt City Council and groups like the Waiwhetu Stream Working Group to restore the Waiwhetu Stream. This includes looking at methods of remediating, or at least isolating, the contaminated sediments, reducing the impacts of stormwater discharges and large scale riparian planting.

(h) Mangatarere Stream

Water quality in the Mangatarere Stream at State Highway 2 received a WQI grade of poor although macroinvertebrate health was fair. This site is located in an intensive dairying catchment but, unlike other such catchments in the region (e.g., Waitohu, Mangaone), it did not show a significant improvement in water quality over the reporting period. This suggests that improvements expected with a shift to land-based disposal of dairyshed effluent during the reporting period have been masked by the discharge of municipal wastewater from Carterton (approximately 2 km upstream of State Highway 2), and other agricultural practices (e.g., stock crossings and general stock access). A large piggery is also located upstream of State Highway 2. The impact of the Carterton WWTP discharge is expected to decrease in the future; land-based effluent disposal has been trialled since 2003/2004.

In 2001, a riparian rehabilitation pilot programme began on the lower reaches of the Enaki Stream, a major tributary of the Mangatarere Stream. Results of water quality monitoring on this tributary to date reveal marked improvements in bank stability, decreased water temperatures and algal biomass and, consequently, a more sensitive and diverse macroinvertebrate community (Warr 2004).

(i) Wainuiomata River (mid and lower reaches)

Based on the WQI, water quality was good in the mid reaches (Leonard Wood Park) and poor in the lower reaches (both Wainuiomata Golf Course and White Bridge) of the Wainuiomata River over the reporting period. However, as discussed in Section 5.2.5, significant improvements in water quality (decreasing dissolved nutrient concentrations and faecal coliform counts) were observed at the latter two (downstream) sites over the reporting period, coinciding with the removal of the Wainuiomata WWTP discharge in November 2001. Improvements were also evident in macroinvertebrate health at both Leonard Wood Park and the Wainuiomata Golf Course (refer Section

5.3). The reason for the improvement at Leonard Wood Park is unclear; this site is located approximately 0.3 km upstream of the Wainuiomata WWTP.

6.1.4 Other problem rivers and streams in need of enhancement

Analysis of monitoring data collected from the RSoE monitoring programme over the 1997-2003 reporting period has identified sites with poor physico-chemical and microbiological water quality on several other rivers and streams that are not specifically mentioned in the RPS or RFP. These include the lower reaches of the Whangaehu River (above its confluence with the Ruamahanga River), the Mangaroa River (Te Marua), and the Waitohu Stream (Norfolk Crescent). The lower reaches of these waterbodies are located in dairy catchments and frequently exceed nutrient and microbiological water quality guidelines, although water quality improved significantly in the lower Waitohu Stream over the reporting period (refer Section 5.2.1). In contrast, no significant changes in water quality were observed in the lower Whangaehu River and significant increasing trends in conductivity and ammoniacal nitrogen concentrations were observed in the lower Mangaroa River (1.06 uS/cm per year and 0.010 mg/L per year respectively, flow-adjusted data). It is possible that water quality at the latter site may improve in the future with the progressive removal of a significant discharge of piggery wastewater from the lower catchment over the last few years. Monitoring data collected since August 2003 should be analysed for this site to determine whether there has already been an improvement. Similarly recent data should be reviewed for the other sites classified with poor water quality over the reporting period.

Although classified with fair water quality under the WQI, the Karori Stream at Makara Peak and Porirua Stream at Wall Park are also considered to be in need of enhancement. Both sites recorded very high levels of microbiological contamination (refer Section 4.3.13) and despite a significant decrease in faecal bacteria counts in the Porirua Stream over the reporting period (refer Section 5.2.7), more recent monitoring of *E. coli* bacteria counts confirms that bacteria levels remain well above recommended guidelines (Figure 6.5). Microbiological contamination is discussed in more detail in Section 6.2.

A riparian rehabilitation pilot programme began on a 1.3 km stretch of the Karori Stream at the Makara Peak Mountain Bike Park in 2001. Results of water quality monitoring upstream and downstream of this site to date have not detected any change in the health of Karori Stream (Warr 2004). Impacts from urban stormwater and possibly sewer cross-connections are likely to be primarily responsible for the poor health of the stream.

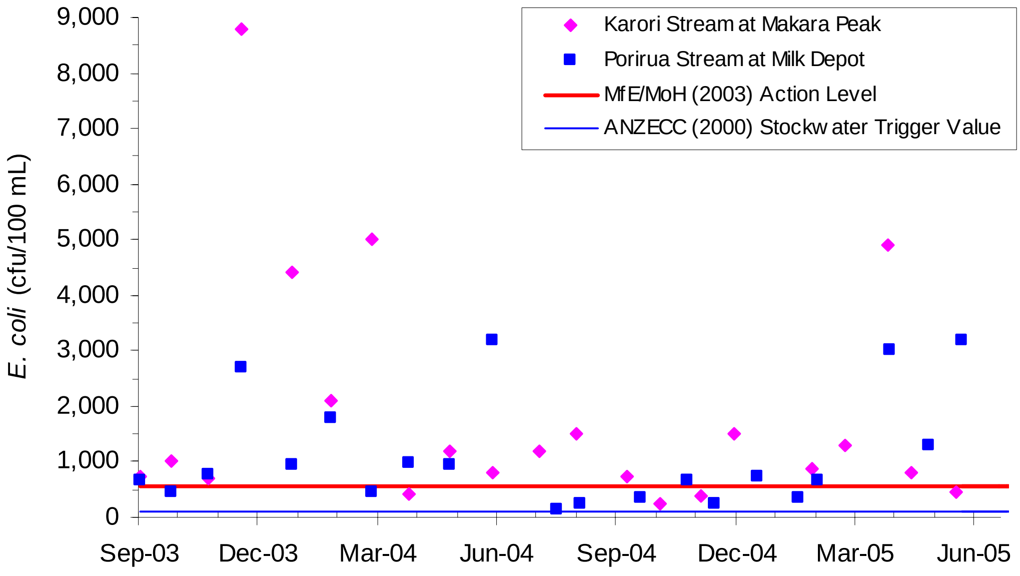


Figure 6.5: ***E. coli*** counts recorded in Karori Stream at Makara Peak and Porirua Stream at Wall Park over August 2003 to May 2005 inclusive, together with microbiological water quality guidelines for freshwater recreational areas (MfE/MoH 2003) and stock water (ANZECC 2000).

6.2 Water quality problems

Two features of the RSoE monitoring results are the degree of microbiological contamination present at many sites and the degraded state of urban streams.

6.2.1 Microbiological contamination

Elevated faecal coliform bacteria counts were recorded at most low elevation RSoE sites draining urban and pastoral catchments (Figure 6.6). This observation is not unique to the Wellington region; Larned et al. (2004) found elevated faecal bacteria counts at similar sites across the country.

While urban streams in the Wellington region are not commonly used for recreational activities such as swimming or kayaking, the very high levels of faecal bacteria indicate a likely health risk to children playing in streams, people biking through streams, or people collecting watercress. Moreover, many urban streams discharge into coastal waters used for contact recreation (e.g., Owhiro Stream in Wellington City discharges to the coast at Owhiro Bay).

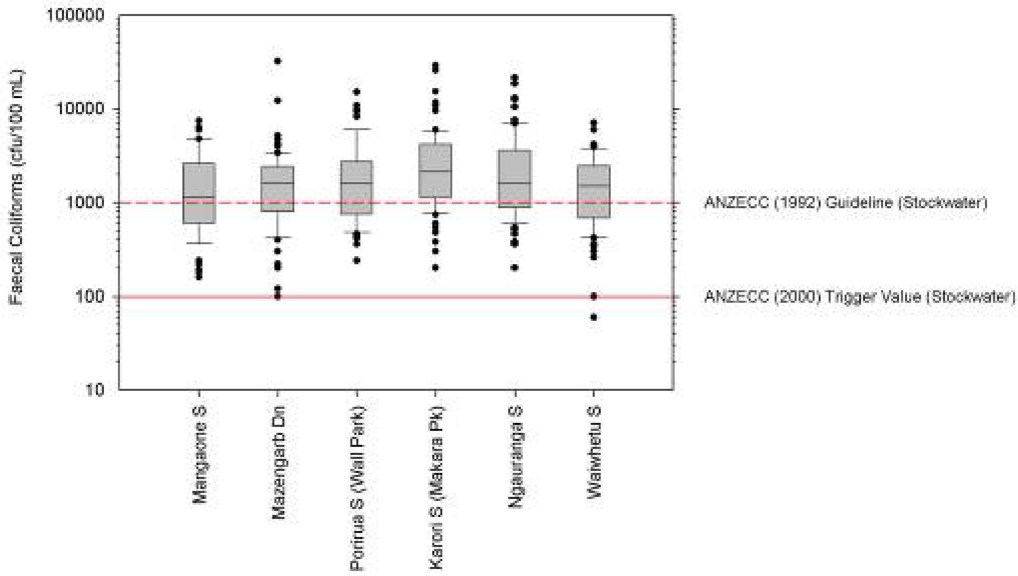


Figure 6.6: Box plot summarising faecal coliform bacteria counts recorded at six urban and rural RSoE sites over July 1997 to July 2003 inclusive. All six sites recorded median counts above 1,000 cfu/100 mL (n=71-73).

The primary sources of microbiological contamination in urban streams are stormwater runoff and sewer leaks and overflows. In the Wellington region, the percentage of wastewater pipes 50 years or older is high by average standards in New Zealand, and there are a larger number of smaller diameter pipes due to the steep topography (Capacity 2005). Consequently, during heavy rainfall, parts of the wastewater system lack sufficient capacity to cope with the increased flows that can result from stormwater or groundwater entering the system, resulting in overflows of diluted sewage to streams and the coast.

As outlined in Section 5.2.7, the Wellington City Council has undertaken a range of works to reduce these overflow events and improve water quality in urban streams over the last 10 or so years. While significant improvements have been made in some catchments (e.g., the central city suburbs that drain to Overseas Passenger Terminal stormwater outfall), little improvement has been evident in other catchments (e.g., Ngauranga Stream).

In contrast to urban streams, many rivers and streams in rural areas are popular for recreational activities; at least 10 of the 23 freshwater sites monitored under the Greater Wellington's Recreational Water Quality Monitoring Programme drain catchments with pasture land cover in excess of 25 %. With few point-source discharges of agricultural effluent remaining in the region since 2004, municipal and on-site wastewater discharges, and diffuse run-off and stock access (Figure 6.7) are considered the most common sources of microbiological (and general) contamination in rural rivers and streams.

Figure 6.7: Clear evidence of recent stock access (dairy cows) to a branch of the Whangaehu River.

6.2.2 Degraded urban streams

All nine of the 51 RSoE monitoring sites draining predominantly urban catchments had degraded water quality (fair or poor WQI grades), with all sites recording elevated concentrations of faecal bacteria and nutrients, in particular, nitrate nitrogen. However, water quality grades did not always correlate with macroinvertebrate health. For example, Porirua Stream at Wall Park and Owhiro Stream at Mouth recorded fair WQI grades (median values of just two of the 6 WQI variables exceeded guideline values), yet scored poor grades across all four macroinvertebrate indices.

The lack of agreement between the physico-chemical characteristics of these streams and assessments of their macroinvertebrate communities suggests that the current RSoE monitoring programme may not be accurately reflecting water quality conditions in some urban streams. Diurnal variation in dissolved oxygen, pH and water temperature, as well as contamination by stormwater pollutants such as silt, heavy metals and hydrocarbons are other factors that may be impacting on water quality and macroinvertebrate health at some sites. Investigations into contamination of urban stream sediments across the Wellington region undertaken in May 2005 identified elevated concentrations of contaminants at some urban RSoE sites (Table 6.4), including DDT, lead and zinc (Croucher and Milne 2005).

Table 6.4: Summary of sediment contamination identified in streams where RSoE monitoring is undertaken, based on single composite samples collected in May 2005. Only contaminants exceeding ANZECC (2000) Interim Sediment Quality Guidelines (ISQG) are shown.

Stream	ISQG Low Exceedances	ISQG High Exceedances
Pauatahanui Stream	DDT	
Porirua Stream	DDT	Lindane
Karori Stream	DDT, zinc	
Owhiro Stream	DDT, lead, zinc	Dieldrin, lindane
Kaiwharawhara Stream	DDT, dieldrin, low molecular weight polyaromatic hydrocarbons, nickel, lead, zinc, polychlorinated biphenols	High molecular weight polyaromatic hydrocarbons
Ngauranga Stream	Zinc	

Note: The low and high trigger values represent a statistical probability of adverse effects on aquatic ecosystems of 10% and 50% respectively.

In addition to habitat modifications (e.g., stream realignment, culverting, filling in of first-order streams, removal of riparian vegetation) and contaminated stormwater inputs, pollution incidents are another major contributing factor to poor water quality in Wellington's urban streams. Records from Greater Wellington's 24-hour Pollution Hotline indicate that pollution incidents are commonly reported in the urban areas of the Wellington region (Figure 6.8). For the year ending 30 June 2005 inclusive, 37 % of reported incidents were attributed to a combination of stormwater and surface water pollution by silt (Figure 6.9), oil, paint and other contaminants (Greater Wellington Regional Council 2005a).

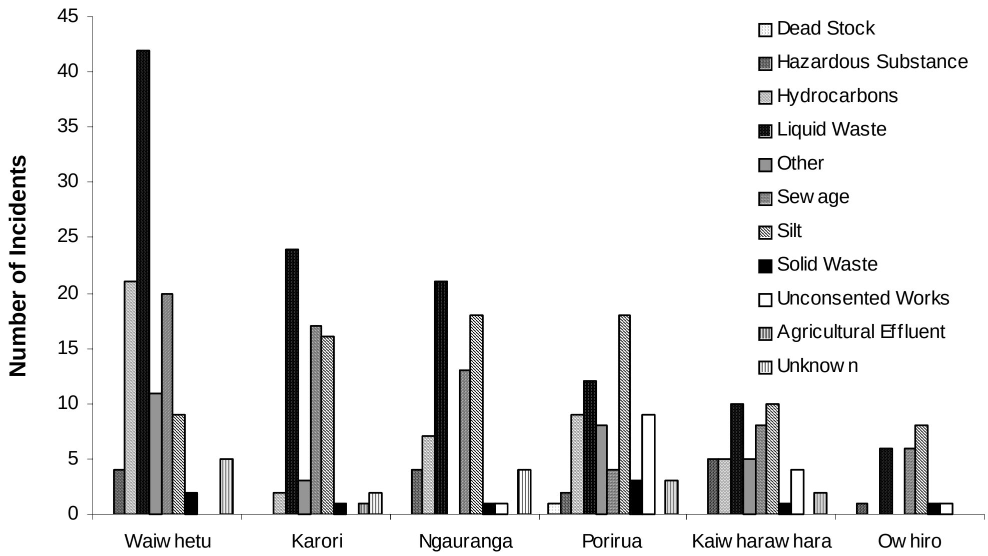


Figure 6.8: The number and type of pollution incidents reported to Greater Wellington's 24-hour Pollution Hotline in selected urban streams monitored in the RSoE programme. The totals shown are for the period from 1990 till June 2001. Caution should be exercised in comparing the number of incidents at sites as the numbers recorded may be highly correlated to the surrounding population of people able to observe the incidents.

(Source: Warr 2001)

Figure 6.9: Silt discharge to a tributary of the Owhiro Stream. Silt pollution from residential subdivision developments has become increasingly more common in recent years as a result of developers clearing and building on steeper sites.

6.2.3 Responses to water quality problems

A range of initiatives have been and continue to be undertaken to address poor water quality in rivers and streams in the Wellington region. These include:

- The development and adoption of a riparian strategy to improve streamside management and minimise the impacts of rural land use on rivers and streams. This strategy was adopted in 2002 and has resulted in the establishment of three riparian rehabilitation pilot projects in the Kakariki Stream near Waikanae, the Karori Stream in Wellington City and the Enaki Stream near Carterton. These pilot projects incorporate regular water quality and biological monitoring so that the benefits of riparian rehabilitation can be measured.

- *Streams Alive*, a programme borne out of the riparian strategy which provides financial assistance to landowners in 12 high value catchments in need of protection. These catchments include Ration and Glendhu Creeks, the Waitohu, Karori, Owhango and Waihora Streams, and the Otaki Mangaroa, Wainuiomata, Kaiwhata, Waiohine and upper Ruamahanga Rivers.

- *Take Charge*, a pollution prevention programme that aims to improve the environmental performance of participating industries across the region. The programme provides an environmental assessment of facilities, activities and management procedures.

- *Take Care*, a programme that provides funding and support for local community groups undertaking projects to improve the environment. In 2005, there were more than 33 groups with 25 of these working on freshwater related projects such as riparian planting or wetland restoration.

- *Take Action*; an environmental education programme for schools that aims to show children aged 8-12 years how to care for rivers and streams.

- *Muddy Waters*, a project that provided information to developers and contractors on ways to reduce the effects of silt runoff on watercourses in areas under development pressure.

- *Be the Difference*, a social marketing campaign to raise awareness of the impacts of people's everyday activities on water quality in rivers and streams.

- Ongoing investigations into contaminated stormwater and receiving waters to identify and quantify problem areas.

- Release of an Issues and Options document for stormwater management in the Wellington region (Greater Wellington Regional Council 2005b), with the view to establishing a working party with territorial authorities to address stormwater management issues.

- Assessments of the ecology of urban streams throughout the Wellington region to help review the policy framework for managing the use and development of urban streams and the land in their catchments.

- Adoption of a Regional Action Plan with Fonterra Co-operative Group to implement the Dairying and Clean Streams Accord with Fonterra in the Wellington region. The aim of the accord is to reduce the impacts of dairying practices on receiving waters.

- Ongoing development and review of minimum flow requirements for rivers and streams in the region, to reduce the effects of low flows on water quality and instream fauna.

- Ongoing compliance monitoring of consented activities in the region with potential to impact on surface water resources.

One initiative not used widely to date is targeted water quality investigations or catchment-specific monitoring programmes. Greater use of these programmes is recommended for sites with poor water quality (e.g., lower Mangaroa River).

6.3 Limitations of the RSoE monitoring programme

Reporting on the state of the environment, in particular, compliance with RPS and RFP management objectives, using information drawn from the RSoE monitoring programme has been difficult for a number of reasons. These largely relate to the nature and scope of monitoring undertaken to date:

- Up until August 2003, surface water quality monitoring was conducted under two separate monitoring programmes, with some differences present in the suite of water quality parameters and the laboratory analytical methods employed (refer Section 2).

- Habitat quality, a major influence on ecological health, was not assessed during the reporting period.

- Temporal trend analyses have largely been limited to raw water quality records because flow information was not available for many RSoE sites. Therefore flow effects can not be ruled out as being a contributing factor to the reported trends. Moreover, other trends may have been present but were masked by the effects of flow. For example, in analysing trends in river water quality in the Waikato region, Vant and Smith (2004) identified 589 significant trends in flow-adjusted records, of which 130 (22%) were not seen in the raw records.

- Resource consent related monitoring information that may have assisted in interpreting water quality trends at RSoE sites (e.g., municipal wastewater and receiving water quality data) is not easily accessible from Greater Wellington's information storage system. Relevant resource consent monitoring information needs to be identified and entered onto Greater Wellington water quality database for use in future reporting.

- Not all waterbodies listed in the RPS or RFP to be enhanced for aquatic ecosystem health or other purposes are included in the RSoE monitoring programme. Examples include the Waikanae River Estuary, Tikotu Stream, Hulls Creek, and Makoura Stream. In addition, two other waterbodies listed in the RPS and RFP and discussed in this report – the Mazengarb Drain and Ngauranga Stream – were dropped from the RSoE programme in August 2003.

While it is important that monitoring information is collected at sites listed in the RPS and RFP for the purposes of determining whether management objectives are being met, it is not possible or probably appropriate to monitor all of these sites under the RSoE programme. In many cases water quality information is already being collected by other organisations as part of their routine monitoring programmes or to fulfil resource consent requirements. For example, some water quality variables are monitored in the Mazengarb Drain and Tikotu Stream by Kapiti Coast District Council, in selected urban streams (e.g., Karori Stream, Ngauranga Stream, Owhiro Stream) by Wellington City Council, and in the Makoura Stream by Masterton District Council. Where water quality information is not readily available for a waterbody listed under the RPS or RFP, the use of targeted water quality investigations should be considered to obtain this information.

To further improve the RSoE programme, consideration should be given to:

- Establishing a formal quality assurance programme for the collection, processing and storage of all surface water quality information. This is essential because during the process of preparing this report it became apparent that not all historical electronic data records are of adequate quality.

- Installation of flow recorders at RSoE monitoring sites, together with provision for continuous measurements of key water quality information such as dissolved oxygen, pH and water temperature during the summer months. Flow records not only assist in the determination of temporal trends in water quality, but also enable pollutant loads to be calculated.

- Broadening the scope of analytes to include:
  - Selected stormwater contaminants (e.g., heavy metals) at RSoE sites draining urban catchments; and
  - Major anions and cations (for a short fixed period) to better characterise the chemical composition of the water at the RSoE sites, thereby improving our understanding of potential surface water-groundwater interactions and the suitability of water for irrigation or other purposes.

- Developing a formal fish monitoring programme for selected RSoE monitoring sites. Fish are a widely recognised part of river ecosystems from a public perspective, and an important component of river biodiversity. Fish abundance and species diversity have been found to be strongly related to habitat quality.

- Development of region-specific water quality guidelines, using long-term water quality records from appropriate reference sites. The use of "one size fits all" guidelines does not address the natural diversity of the region's river and stream ecosystems. Consequently, non-compliance with a guideline is not necessarily an indication that the site is degraded (e.g., some small, low-gradient streams on the Kapiti Coast draining peaty soils).

In addition to the above, consideration could be given to reviewing the monitoring sites on the Hutt River and the Ruamahanga River given that NIWA also has several long-term water quality monitoring sites on these rivers (refer Section 5.2.4 and Section 5.2.6).

7. Conclusions and recommendations

Physico-chemical and microbiological water quality in rivers and streams across the Wellington region shows a clear spatial pattern related to climate, source of flow, geology and, in particular, land cover. Water quality is highest at RSoE sites located on cool wet, hill-fed river and stream reaches with hard sedimentary geology and unmodified indigenous forest cover. These sites tend to be associated with the Tararua, Rimutaka and Aorangi Ranges and include the Otaki River at Pukehinau, Wainuiomata River at Manuka Track, Hutt River at Te Marua, Waiohine River at the Gorge, and the Ruamahanga River at Mount Bruce. Water quality is generally lower in lowland reaches under indigenous forest cover, and lower again at sites located in pastoral catchments. Water quality is particularly poor at some sites draining dairy catchments, including the lower reaches of the Mangaone Stream, Mangaroa River, Mangatarere Stream and the Whangaehu River. Overall, water quality is poorest at sites draining urban catchments, with the Mazengarb Drain, Ngauranga Stream, and Waiwhetu Stream recording the lowest water quality of the nine urban sites monitored. Significant microbiological contamination is present in many urban streams.

Macroinvertebrate community health exhibits a similar spatial pattern to physico-chemical and microbiological water quality. However, discrepancies between water quality and macroinvertebrate health exist at some RSoE sites, particularly urban sites. These discrepancies suggest that the current RSoE monitoring programme may not be accurately reflecting water quality conditions in some urban streams. Diurnal variation in dissolved oxygen concentrations, pH and water temperature, as well as contamination by stormwater pollutants such as silt, heavy metals and hydrocarbons may be more strongly influencing water quality and the macroinvertebrate communities.

Significant temporal trends in water quality were only apparent at a small number of the 51 RSoE sites and were largely confined to lowland rivers or streams influenced by agricultural or municipal wastewater discharges that had ceased during the reporting period. These include the lower reaches of the Waitohu Stream, Mangaone Stream, Ngarara Stream, and the Wainuiomata River. Many of the other trends observed were confined to one or two water quality variables and are difficult to explain, largely because flow-adjusted water quality records were only available for 14 sites (i.e., flow effects can not be ruled out as being a contributing factor to the majority of observed trends). Lower detection limits and standardisation of laboratory analytical methods since August 2003 should help improve future trend reporting.

The RPS and RFP require some reaches on rivers and streams to be managed for specific purposes, including natural state, fishery and fish spawning, and enhancement for aquatic ecosystem health, or fishery and fish spawning purposes. Analysis of monitoring data collected from the RSoE monitoring programme over the 1997-2003 reporting period indicates that:

- RSoE sites located on river and stream reaches that are to be managed in their natural state consistently record very good water quality and healthy macroinvertebrate communities.

- Thirteen of the 18 RSoE sites on river and stream reaches that are managed for fisheries have good or very good water quality and macroinvertebrate communities. The other five sites have considerably lower water quality; Kopuaranga Stream at Stewarts, Taueru River at Gladstone, Mangaroa River at Kalcoolies Corner and Te Marua, and the Wainuiomata River at Wainuiomata Golf Course. Of these sites, only the Wainuiomata River showed a significant improvement in water quality over the reporting period.

- Water quality at three of the nine RSoE sites located on river and stream reaches in need of enhancement for aquatic ecosystem health purposes showed a significant improvement over the reporting period; the Mangaone Stream at Sims Road Bridge, the Ngarara Stream at Field Way, and Makara Stream at Kennels. Of the remaining sites, two showed a decline in water quality (the lower Mazengarb Drain and Ngauranga Stream), and four showed no change (Makara Stream upstream of Ohariu Stream confluence, Kaiwharawhara Stream at Ngaio Gorge, Waiwhetu Stream at Wainuiomata Hill and Mangatarere Stream at State Highway 2).

- A significant improvement was observed in water quality at all three RSoE sites on the reaches of the Wainuiomata River in need of enhancement for trout fishery habitat and spawning.

Poor physico-chemical and microbiological water quality was identified in several other rivers and streams not specifically mentioned in the RPS or RFP. These include the lower reaches of the Whangaehu River (above its confluence with the Ruamahanga River), the Mangaroa River (Te Marua), and the Waitohu Stream (Norfolk Crescent). The lower reaches of these waterbodies are in dairy catchments and frequently exceed nutrient and microbiological water quality guidelines, although water quality improved significantly in the lower Waitohu Stream over the reporting period.

The Karori Stream at Makara Peak Mountain Bike Park and Porirua Stream at Wall Park are also considered to be in need of enhancement. Both sites recorded very high levels of microbiological contamination. Impacts from urban stormwater and possibly sewer cross-connections are likely to be primarily responsible for this contamination.

A wide range of initiatives are in place to address poor water quality in rivers and streams in the Wellington region. These include riparian rehabilitation projects, the *Take Charge* pollution prevention programme, the *Take Action* environmental education programme, public education campaigns such as *Be the Difference*, and ongoing investigations into contaminated stormwater discharges.

7.1 Recommendations

To improve future RSoE monitoring and reporting:

1. Establish a formal quality assurance programme for the collection, processing and storage of all surface water quality information collected under the RSoE programme.

2. Install flow recorders at or near priority RSoE monitoring sites where flow information is lacking, with provision for continuous measurements of key water quality variables such as dissolved oxygen, pH and water temperature during the summer months.

3. Broaden the scope of physico-chemical water quality analytes to include selected stormwater contaminants (e.g., heavy metals) at RSoE sites draining urban catchments and, for a short fixed period at all RSoE sites, major anions and cations.

4. Develop a fish monitoring programme for implementation at selected RSoE monitoring sites.

5. Investigate the development of region-specific water quality guidelines, using long-term water quality records from appropriate reference sites.

6. Identify key surface water quality information of relevance to the RSoE programme collected by resource consent holders and external organisations and collate this for inclusion onto Greater Wellington's Water Quality Database.

7. Undertake targeted catchment water quality monitoring to investigate ongoing poor water quality at selected RSoE sites.

8. Review and revise the list of river or stream reaches specified in the RPS and RFP to be managed for enhancement of water quality as appropriate using the findings of this report, together with more recent water quality information collected under the RSoE programme (i.e., post-August 2003).

References

ANZECC. 1992. *Australian water quality guidelines for fresh and marine waters*. National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC. 2000. *Australia and New Zealand guidelines for fresh and marine water quality, Volume 1, The guidelines*. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Capacity. 2005. *Assessment of water and sanitary services 2005.* Report prepared for Wellington City Council.

Chapman, D.; Kimstach, V. 1998: Selection of water quality variables. In: Chapman, D. (ed.) *Water quality assessments*. 2nd ed. E & FN Spon, London.

Croucher, B.; Milne, J. 2005. *Urban stream sediment quality investigation*. Report prepared for the Greater Wellington Regional Council's Environment Committee. Report No. 05.380.

De Silva, J. 2004. *The impact of the closure and decommissioning of the Wainuiomata Waste Water Treatment Plant on the water quality of the Wainuiomata River*. M.Phil thesis. Massey University, Palmerston North.

Deely, J.; Tunnicliff, J.; Orange, C.; Edgerley, W. 1992. Heavy metals in surface sediments of Waiwhetu Stream, Lower Hutt, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 26: 417-427.

Death, F.; Death, R. 2005. *Analysis of Wellington water quality data for river state of the environment reporting 1999-2004*. Unpublished report prepared for Greater Wellington Regional Council. Massey University, Palmerston North.

Forsyth, K. 2005. *Waste management and hazardous substances – background report.* Greater Wellington Regional Council, Publication No. GW/RP-T-05/301.

Greater Wellington Regional Council. 2005a. *Annual pollution control report, 2004/2005.* Greater Wellington Regional Council, Publication No. GW\RINV-G-05/249.

Greater Wellington Regional Council. 2005b. *Stormwater management: Issues and options for the Wellington region.* Greater Wellington Regional Council, Publication No. GW\RINV-G-05/230.

Hutt City Council. 1998: *Proposed Wainuiomata Sewage Treatment Plant Upgrade.* Coffee, Brian, T & Associates.

Hutt City Council. 2005. *Infiltration and stormwater ingress annual progress report, April 2004 to March 2005.* Unpublished report, Hutt City Council.

Kingett Mitchell Limited. 2005. *Assessment of urban stormwater quality in the Greater Wellington region.* Unpublished report prepared for Greater Wellington Regional Council. Kingett Mitchell Limited, Auckland.

Larned, S.T.; Scarsbrook, M.R.; Snelder, T.H.; Norton, N.J.; Biggs, B.J.F. 2004. Water quality in low-elevation streams and rivers of New Zealand: recent state and trends in contrasting land-cover classes. *New Zealand Journal of Marine and Freshwater Research, 34:* 347-366.

Larned, S.T.; Scarsbrook, M.R.; Snelder, T.H.; Norton, N.J. 2005. *Nationwide and regional state and trends in river water quality 1996-2002*. National Institute of Water and Atmospheric Research, Christchurch.

Milne, J. 2005. *Recreational water quality monitoring technical report*. Greater Wellington Regional Council, Publication No. GW\RINV-T-05/89.

Ministry for the Environment. 2000. *New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams*. Ministry for the Environment, Wellington.

Ministry for the Environment. 2001. *Managing waterways of farms: a guide to sustainable water and riparian management in rural New Zealand.* Ministry for the Environment, Wellington.

Ministry for the Environment; Ministry of Health. 2003[9]. *Microbiological Water Quality Guidelines for Marine and Freshwater Recreation Areas*. Ministry for the Environment, Wellington.

Purchas, C. 1998. *Landfills in the Wellington region.* Wellington Regional Council. Publication No. WRC/RINV-T-98/47.

Quinn, J.M.; Hickey, C.W. 1990. Characterisation and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors. *New Zealand Journal of Marine and Freshwater Research, 24: 387-409.*

Snelder, T.; Biggs, B.; Weatherhead, M.; Niven, K. 2003. *New Zealand River Environment Classification: a guide to concepts and use.* Draft Report CHC 2003-034.

Stansfield, B. 2000. *Wellington Regional Council annual freshwater quality report 1999-2000*. Wellington Regional Council, Publication No. WRC/RINV-T-01/03.

Stark, J.D. 1985. A macroinvertebrate community index of water quality for stony streams. *Water & Soil Miscellaneous Publication 87.* National Water and Soil Conservation Authority, Wellington.

Stark, J.D. 1993. Performance of the Macroinvertebrate Community Index: Effects of sampling method, sample replication, water depth, current velocity, and substratum on index values. *New Zealand Journal of Marine and Freshwater Research, 27*: 463-478.

[9] Published June 2002, updated June 2003.

Stark, J.D. 1998. SQMCI: A biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research, 32*: 55-66.

Stark, J.D.; Boothroyd, I.K.G.; Harding, J.S.; Maxted, J.R.; Scarsbrook, M.R. 2001. Protocols for sampling macroinvertebrates in wadeable streams. *New Zealand Macroinvertebrate Working Group Report No. 1.* Prepared for the Ministry for the Environment, Sustainable Management Fund Project No. 5103.

Stark, J.D.; Maxted, J.R. 2004. *Macroinvertebrate community indices for Auckland's soft-bottomed streams and applications to SOE reporting.* Prepared for the Auckland Regional Council, Cawthron Institute Report No. 970.

Vant, B.; Smith, P. 2004. *Trends in river water quality in the Waikato region, 1987-2002.* Technical Report 2004/02. Environment Waikato, Hamilton.

Warr, S. 2001. *Annual freshwater quality report 2000-2001*. Wellington Regional Council, Publication No. WRC\RINV-G 01/34.

Warr, S. 2002a. *Rivers state of the environment monitoring review*. Wellington Regional Council, Publication No. WRC/PRW-G-02/64.

Warr, S. 2002b. *Water quality and stream health of the Waikanae River: a summary of SoE monitoring data*. Wellington Regional Council, Publication No. WRC/PRW-T-02/63.

Warr, S. 2004. *Riparian rehabilitation – what difference does it make? Preliminary monitoring results from the Riparian Management Pilot Programme.* Greater Wellington Regional Council, Publication No. GW\PRW-G-04/36.

Watts, L. 2001. *Wairarapa municipal oxidation ponds: water quality monitoring report, July 1999-June 2001.* Wellington Regional Council, Technical Report No. 01/10.

Watts, L. 2005. *Hydrological monitoring technical report.* Greater Wellington Regional Council, Publication No. GW\RINV-T-05/88.

Wellington Regional Council. 1995: *Regional Policy Statement for the Wellington region*. Wellington Regional Council, Publication No. WRC/PP-G-95/28.

Wellington Regional Council. 1999: *Regional Freshwater Plan for the Wellington region*. Wellington Regional Council, Publication No. WRC/RP-G-99/31.

Wellington Regional Council. 2002. *The state of our environment annual summary: River and stream quality 2001/02.* Greater Wellington Regional Council, Publication No. WRC\RP-G-02/56.

Winterbourn, M.J. 1973. A guide to the freshwater mollusca of New Zealand. *Tuatara 20,* 3: 141-159. 2002.

Winterbourn, M.J.; Gregson, K.L.D. 1985. Guide to the aquatic insects of New Zealand. *Bulletin of the Entomological Society of New Zealand No. 5.*

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Appendix 1: RSoE site history

Site No.	New RSoE Site No.	Site Name	Grid Reference	Water Quality Monitoring History		Biological Monitoring History	REC	% Land Cover Classes (simplified) in Upstream Catchment (Source: MfE Land Cover Database, v2, 2001)							
				Date Started	Current Status			Indigenous Forest	Exotic Forest	Scrub	High Prod. Pasture	Low Prod. Pasture	Urban	Cropping	Other
FB01	N/A	Waitohu S at Water Supply Intake	S25:969-464	Sep-2000	Historic - relocated u/s Sept 2003	Long-term site, relocated Sept 2003	CW/H/HS/IF	89.1	2.7	4.9	0.8	2.5	0	0	0
FB02	RS04	Waitohu S at Norfolk Cres	S25:894-502	Nov-1991	Current	Monitoring started 2004	CW/L/HS/P	38.7	8.2	3.5	42.8	1.5	3.2	0.8	1.3
FB03	RS05	Otaki R at Pukehinau	S25:955-405	Sep-1991	Current	Long-term site	CW/H/HS/IF	90.1	1.4	5.6	1.2	1.1	0	0	0.6
FB04	RS06	Otaki R at Mouth	R25:880-476	Apr-1990	Current	Long-term site	CW/H/HS/IF	82.7	2.1	5.1	7.3	1.1	0.3	0.3	1.3
FB05	RS07	Mangaone S at Sims Rd Br	S25:862-441	Jul-1997	Current	Monitoring started 2004	WW/L/AL/P	17.3	11.1	0.8	64.2	2.3	1.1	2.1	1.1
FB06	N/A	Waikanae R at Reikorangi Br	R26:854-317	Apr-1990	Historic - relocated u/s Sept 2003	Long-term site, relocated Sept 2003	CW/L/HS/IF	78.9	9.4	0.7	10.9	0	0	0	0.1
FB07	RS08	Ngarara S at Field Way	R26:812-363	Apr-1990	Current	Monitoring started 2004	WW/L/AL/P	19.6	9.8	1	52.6	2.1	10.3	0	4.6
FB08	N/A	Waikanae R at Oxbow Boat Ramp	R26:797-346	Apr-1990	Historic - relocated u/s Sept 2003	Long-term site, relocated Sept 2003	CW/L/HS/IF	61.0	14.5	0.8	21.1	0.5	2	0	0.1
FB09	N/A	Mazengarb Drn u/s Waikanae R	R26:795-344	Jul-1997	Historic - dropped August 2003	No monitoring undertaken	WD/L/M/U	8.6	5.1	2.4	57.8	0	25.6	0	0.6
FB10	N/A	Horokiri S at Ongly	R26:712-116	Jun-1987	Historic - relocated u/s Sept 2003	Long-term site, relocated Sept 2003	CW/L/HS/P	11.4	27.7	14.7	24.9	21.1	0	0.2	0
FB11	RS14	Pauatahanui S at Elmwood Br	R27:711-084	Jul-1997	Current	Long-term site	CW/L/HS/P	20.9	14.7	3.9	59.7	0.1	0.4	0	0.2
FB12	RS15	Porirua S at Glenside	R27:633-002	Mar-1988	Current	Long-term site	CW/L/HS/U	12.2	3.2	12.1	45	0.4	26.5	0	0.7
FB13	RS16	Porirua S at Wall Pk (Milk Station)	R27:646-048	Aug-1987	Current	Long-term site	WW/L/HS/U	11.4	8.9	10.7	40	0.4	28.3	0	0.3
FB14	N/A	Ohariu S 50m u/s Makara Stream	R27:542-951	Jul-1987	Historic - dropped August 2003	Long-term site until Aug 2003	CW/L/HS/P	2.4	6.2	12.1	79	0	0.3	0	0
FB15	N/A	Makara S u/s Ohariu Stream	R27:540-949	Jan-1988	Historic - dropped August 2003	No monitoring undertaken	CW/L/HS/P	4.9	12.1	45.3	37.2	0.3	0.2	0	0
FB16	RS17	Makara S at Kennels	R27:535-955	Jul-1987	Current	Long-term site	CW/L/HS/P	3.3	8.1	22.3	66	0.1	0.2	0	0
FB17	RS18	Karori S at Makara Peak	R27:542-885	Apr-1988	Current	Monitoring started 2004	CW/L/HS/U	42.7	1.7	3.4	5.5	0	46.8	0	0
FB18	N/A	Karori S d/s Sth Makara Stream	R27:510-868	Jul-1997	Historic - dropped August 2003	Long-term site until Aug 2003	CW/L/HS/U	27.6	3.4	43.6	7.5	3.4	14.4	0	0
FB19	N/A	Owhiro S at Mouth	R27:572-833	Mar-1988	Historic - dropped August 2003	Long-term site until Aug 2003	CW/L/HS/U	28.7	2.4	43.2	0.7	3.2	17.8	0	4.1
FB20	RS19	Kaiwharawhara S at Ngaio Gorge	R27:592-928	Jun-1987	Current	Long-term site	CW/L/HS/U	34.5	6.1	12.5	11.1	0	35.6	0	0.2
FB21	N/A	Ngauranga S 400m u/s Mouth	R27:619-943	Jun-1987	Historic - dropped August 2003	Long-term site until Aug 2003	CW/L/HS/U	21.1	0.4	9.7	8.7	0	60	0	0
FB22	RS20	Hutt R at Te Marua Water Intake	S26:901-119	May-1987	Current	Long-term site	CX/H/HS/IF	84.5	3.4	6.2	5.4	0.2	0.1	0	0.2
FB23	N/A	Hutt R at Birchville Canoe Club	R26:862-108	Aug-1987	Historic - dropped August 2003	Long-term site until Aug 2003	CW/H/HS/IF	73.3	9.9	3.9	11.1	0.9	0.4	0	0.4
FB24	RS21	Hutt R opp. Manor Park G.C.	R27 767-040	Jul-1997	Current	Long-term site	CW/H/HS/IF	67.6	12.8	3.8	11.3	1	2.9	0	0.6
FB25	N/A	Hutt R u/s of Melling Br	R27:706-990	Jul-1997	Historic - relocated u/s Sept 2003	Long-term site, relocated Sept 2003	CW/L/HS/IF	65.7	11.9	4.2	12.2	1	4.2	0	0.7
FB26	RS23	Pakuratahi R 50m d/s Farm Ck	S26:945-134	Dec-1987	Current	Long-term site	CX/H/HS/IF	69.7	8.4	9.4	11.7	0.3	0.1	0	0.4
FB27	N/A	Mangaroa R at Kalcoolies Cnr	R27:831-003	May-1987	Historic - dropped August 2003	Long-term site until Aug 2003	CW/L/HS/P	25.0	22.9	3	46.5	2	0.3	0	0.3
FB28	RS24	Mangaroa R at Te Marua	R26:886-104	Sep-1987	Current	Long-term site	CW/L/HS/P	47.9	15.6	2.9	30.7	1.3	1.1	0	0.5
FB29	RS25	Akatarawa R u/s Hutt R confl.	R26:862-109	Jul-1997	Current	Long-term site	CW/L/HS/IF	79.1	16.1	1.4	1.8	1.6	0	0	0
FB30	RS27	Waiwhetu S at Wainui Hill Br	R27:707-958	Jun-1987	Current	Monitoring started 2004	WW/L/HS/U	26.0	0.5	17.8	3.5	0	52.2	0	0
FB31	RS28	Wainuiomata R at Manuka Track	R27:784-927	Jun-1987	Current	Long-term site	CW/L/HS/IF	98.9	0.7	0	0.3	0.2	0	0	0
FB32	N/A	Wainuiomata R at L. Wood Pk	R27:732-897	Sep-1987	Historic - dropped August 2003	Long-term site until Aug 2003	CW/L/HS/IF	74.8	2.3	9.4	6	0.5	7	0	0
FB33	N/A	Wainuiomata R at Golf Course	R27:722-874	Dec-1989	Historic - dropped August 2003	Long-term site until Aug 2003	CW/L/HS/IF	73.8	2.3	10.4	6.3	0.5	6.6	0	0.2
FB34	RS29	Wainuiomata R u/s of White Br	R28:675-775	Jul-1997	Current	Long-term site	CW/L/HS/IF	64.7	4.6	15.8	9.7	0.5	4.4	0	0.3
FB35	RS30	Orongorongo R at Orongo. Stn	R28:689-748	Apr-1988	Current	Long-term site	CW/H/HS/IF	82.1	0.2	12.7	0.9	0.8	0	0	3.2
FB36	N/A	Ruamahanga R at Mt Bruce	S25 299 450	Nov-1991	Historic - relocated u/s Sept 2003	Long-term site, relocated Sept 2003	CX/H/HS/IF	66.3	0.2	24	7.9	0.3	0	0	1.3
FB37	N/A	Ruamahanga R at Dble Bridges	T26 344 335	Nov-1991	Historic - dropped August 2003	Long-term site until Aug 2003	CX/H/HS/P	51.6	2.5	17.5	25.5	0.3	0	0.1	2.5
FB38	RS32	Ruamahanga R at Te Ore Ore	S27 257 089	Feb-1997	Current	Long-term site	CW/L/SS/P	21.2	3.1	6.8	67.1	0.1	0.3	0.1	1.4
FB39	RS33	Ruamahanga R at Gladstone Br	T26 309 116	Feb-1997	Current	Long-term site	CW/L/SS/P	16.6	7.4	4.4	67.8	1.6	0.8	0.6	0.9
FB40	N/A	Ruamahanga R at Waihenga Br	S27 145 982	Sep-1996	Historic - dropped August 2003	Long-term site until Aug 2003	CW/L/SS/P	21.2	5.5	3.8	65.8	1.3	0.6	1	0.9
FB41	RS38	Kopuaranga S at Stewarts	T26 365 318	Feb-1997	Current	Long-term site	CW/L/SS/P	4.9	3.5	0.8	90.7	0	0	0	0.1
FB42	N/A	Whangaehu R at Waihi	T26:441-378	Nov-1998	Historic - dropped August 2003	No monitoring undertaken	CW/L/SS/P	4.5	12.9	0.4	82.1	0	0	0	0
FB43	RS39	Whangaehu R 250 u/s confl.	T26 373 218	Feb-1997	Current	Long-term site	CD/L/SS/P	3.0	5.4	0.2	90.5	0.1	0	0.8	0.1
FB44	RS40	Waipoua R at Colombo Rd Br	T26 346 256	Feb-1997	Current	Long-term site	CW/L/HS/P	21.4	1.5	2.1	70.5	0.3	2.6	1.1	0.5
FB45	RS41	Waingawa R at South Rd	T26 308 226	Nov-1991	Current	Long-term site	CX/H/HS/IF	56.5	3	19.1	15.1	3.6	0.2	0.1	2.2
FB46	RS37	Taueru R at Gladstone	S26:341-125	Feb-1997	Current	Long-term site	CD/L/SS/P	6.8	14.3	1.2	75.1	2.5	0	0	0.1
FB47	RS47	Waiohine R at Gorge	S26 118 177	Nov-1991	Current	Long-term site	CX/H/HS/IF	82.4	0.9	15.3	0.2	0.1	0	0	0.9

Site No.	New RSoE Site No.	Site Name	Grid Reference	Water Quality Monitoring History		Biological Monitoring History	REC	% Land Cover Classes (simplified) in Upstream Catchment (Source: MfE Land Cover Database, v2, 2001)							
				Date Started	Current Status			Indigenous Forest	Exotic Forest	Scrub	High Prod. Pasture	Low Prod. Pasture	Urban	Cropping	Other
FB48	RS48	Waiohine R at Bicknells	S27 211 093	Nov-1991	Current	Long-term site	CW/H/HS/P	54.5	3.6	7.5	31.3	1	0.6	0.3	1.2
FB49	RS50	Mangatarere R at SH2	S26 198 138	Feb-1997	Current	Long-term site	CW/L/HS/P	42.4	6.6	0.3	45.6	3.1	1.6	0	0.3
FB50	RS51	Huangarua R at Ponatahi Br	S27 185 934	Feb-1997	Current	Long-term site	CD/L/SS/P	18.0	3.5	0.5	75	1.6	0	1.2	0.1
FB51	RS55	Tauherenikau R at Websters	S27 063 011	Nov-1991	Current	Long-term site	CW/H/HS/IF	72.2	1.4	7.5	17.3	0	0	0	1.6
N/A	RS01	Mangapouri S at Rahui Rd	S25 939-456	Sep-2003	Current	Monitoring started 2004	WD/L/Al/U	9.5	1.5	0	88.8	0	0	0.2	0
N/A	RS02	Mangapouri S at Bennetts Rd	S25 907-492	Sep-2003	Current	Monitoring started 2004	WD/L/Al/P	2.6	2.5	1.4	58.0	0	31.7	3.7	0
N/A	RS03	Waitohu S at Forest Park	S25:987-443	Sep-2003	Current	Monitoring started 2004	CW/H/HS/IF	94.4	0	3.6	0	2.0	0	0	0
N/A	RS09	Waikanae R at Mangaone Walkway	R26:899-347	Sep-2003	Current	Monitoring started 2004	CW/L/HS/IF	86.1	11.7	0	2.2	0	0	0	0
N/A	RS10	Waikanae R at Greenaway Rd	R26:815-347	Sep-2003	Current	Monitoring started 2004	CW/L/HS/P	65.0	15.2	0.9	17.6	0.5	0.8	0	0.1
N/A	RS11	Whareroa S at Waterfall Rd	R26 785-286	Sep-2003	Current	Monitoring started 2004	WW/L/HS/P	20.7	23.4	21.6	24.7	9.6	0	0	0
N/A	RS12	Whareroa S at QE Park	R26 761-260	Sep-2003	Current	Monitoring started 2004	WW/L/HS/P	17.6	8.6	2.3	65.7	0.8	4.2	0	0.9
N/A	RS13	Horokiri S at Snodgrass	R26:718-124	Sep-2003	Current	Monitoring started 2004	CW/L/HS/P	11.0	28.2	15.5	22.3	22.8	0	0.2	0
N/A	RS22	Hutt R at Boulcott	R27:708-992	Sep-2003	Current	Monitoring started 2004	CW/L/HS/IF	65.7	11.9	4.2	12.2	1.0	4.3	0	0.7
N/A	RS26	Whakatiki R at Riverstone	R27 818-086	Sep-2003	Current	Monitoring started 2004	CW/L/HS/S	65.1	24.0	2.4	6.8	1.6	0	0	0
N/A	RS31	Ruamahanga R at McLays	S25 274-474	Sep-2003	Current	Monitoring started 2004	CX/H/HS/S	71.8	0	27.0	0.1	0	0	0	1.1
N/A	RS34	Ruamahanga R at Pukio	S27 999-885	Sep-2003	Current	Monitoring started 2004	CW/L/SS/P	20.7	5.7	3.7	66.2	1.2	0.6	1.0	0.9
N/A	RS35	Mataikona Trib. at Sugar Loaf Rd	U25:817526	Sep-2003	Current	Monitoring started 2004	CW/L/SS/P	61.9	6.8	0	19.2	12.1	0	0	0
N/A	RS36	Taueru R at Castlehill	T25 623-457	Sep-2003	Current	Monitoring started 2004	CW/L/SS/P	18.9	15.7	17.8	47.5	0.0	0	0	0
N/A	RS42	Whareama R at Gauge	T26 674-213	Sep-2003	Current	Monitoring started 2004	WW/L/SS/P	11.2	18.3	1.1	68.1	1.2	0	0	0
N/A	RS43	Motuwaireka S at Headwaters	T26 620-120	Sep-2003	Current	Monitoring started 2004	CW/L/HS/S	67.4	31.8	0	0.1	0	0	0	0.8
N/A	RS44	Totara S at Stronvar	T26 573-081	Sep-2003	Current	Monitoring started 2004	CW/L/HS/EF	1.5	93.5	3.2	1.8	0	0	0	0
N/A	RS45	Parkvale trib. at Lowes Reserve	S26 288-200	Sep-2003	Current	Monitoring started 2004	WD/L/Al/P	0	15.1	0	68.5	16.4	0	0	0
N/A	RS46	Parkvale S at Weir	S26 234-112	Sep-2003	Current	Monitoring started 2004	WD/L/Al/P	0.5	1.5	0.2	97.5	0.3	0	0	0.1
N/A	RS49	Beef Ck at Headwaters	S26 139-181	Sep-2003	Current	Monitoring started 2004	CW/L/HS/S	99.2	0.1	0.6	0	0	0	0	0
N/A	RS52	Tauanui R at Whakatomotomo Rd	S28 007-761	Sep-2003	Current	Monitoring started 2004	CW/H/HS/IF	99.8	0	0.2	0	0	0	0	0
N/A	RS53	Awhea R at Tora Rd	T28 374-779	Sep-2003	Current	Monitoring started 2004	WW/L/SS/P	25.6	9.8	0.2	60.4	3.1	0	0	0.9
N/A	RS54	Coles Ck Trib. at Lagoon Hill Rd	S28 246-774	Sep-2003	Current	Monitoring started 2004	WW/L/SS/S	90.1	0	0	7.0	2.9	0	0	0
N/A	RS56	Waiorongomai R at Forest Park	R27 865-923	Sep-2003	Current	Monitoring started 2004	CW/H/HS/IF	98.4	0	1.3	0	0.2	0	0	0.1

Appendix 2: Water quality variables and analytical methods

As far as practicable, individual RSoE monitoring sites are sampled at the same time of the month and at the same time of the day throughout the year, with all sites on an individual river or stream sampled on the same day. Water samples (spot samples) are collected in mid stream, on a representative stretch of the stream, usually a run[10]. Over the 1997-August 2003 reporting period, water temperature, dissolved oxygen and visual clarity (black disc) measurements were taken in the field. Conductivity and pH measurements were generally made in the laboratory, along with analyses for turbidity, faecal coliforms, BOD_5, total organic carbon, and nutrients. Since August 2003, pH and conductivity measurements have been performed in the field.

Table A2:1 outlines the key water quality variables monitored in the RSoE monitoring programme up until August 2003. Laboratory analyses were performed by Greater Wellington Regional Council's laboratory (RSoE sites in the western part of the Wellington region) and Wairarapa Laboratory Services Ltd (eastern/Wairarapa RSoE sites). Table A2:2 lists the analytical methods and detection limits utilised by these laboratories. All water samples were transported to the laboratories in chilli bins containing ice.

Table A2:1: Key water quality variables monitored in the RSoE monitoring programme over the reporting period (1997-2003).

Water Quality Variable	Explanation/Relevance
Water Temperature	- Indicator of biological activity – temperature affects the functioning of aquatic ecosystems and the physiology of biota, including cell function, enzyme activity, bacteriological reproduction rates, and plant growth rates. - Requirement for aquatic life (e.g., temperatures >20 °C can stress trout). - Influences dissolved oxygen concentrations (the higher the temperature, the lower the oxygen concentration) and can affect the toxicity of certain pollutants such as ammonia.
Dissolved Oxygen (DO)	- Essential for aquatic life - concentrations less than 5 mg/L adversely affect trout and concentrations of 2-3 mg/L may result in fish kills. - Indicator of organic pollution (e.g., sewage) - DO concentrations are reduced as bacteria require oxygen to break organic matter down. - Indicator of photosynthesis (plant growth).
pH	- Protection of aquatic life - particularly high (alkaline) or low (acidic) pH levels may adversely impact on aquatic biota. Alkaline conditions may also increase the toxicity of certain pollutants such as ammonia. - Indicator of industrial discharges.
Conductivity	- Indicator of total salts/mineral content - the lower the value, the purer the water is. Wastewater/effluents therefore have higher concentrations of minerals than natural water and a large increase in the conductivity in a water body can often be traced back to wastewater discharges.

[10] A run is defined as a place where the water velocity is uniformly moderately-low (e.g., 0.2-0.4 m/s) and the water depth is 0.2-0.6 m.

Table A2:1 ***cont.***: Key water quality variables monitored in the RSoE monitoring programme over the reporting period (1997-2003).

Water Quality Variable	Explanation/Relevance
Visual Clarity & Turbidity	- Aesthetic appearance. - Aquatic life protection - differences in water clarity affect the ability of sight-feeding predators (e.g., fish, birds) to locate prey and the ability of algae to photosynthesise and hence provide food for animals further up the food chain. - Light availability for excessive plant growth. - Indicator of catchment condition, land use.
BOD_5	- A measure of the oxygen required by bacteria, under standard conditions, to oxidise carbonaceous organic material into a stable inorganic form (carbon dioxide and water) – therefore BOD_5 is an indicator of the amount of biodegradable organic matter present in the water, and the potential for bacteria to deplete oxygen concentrations (e.g., as a result of discharges to water containing waste matter rich in organic matter such as dairy shed and piggery effluent).
Total Organic Carbon	- Indicator of organic carbon content of a waterbody – provides a quick and convenient way of determining the degree of organic contamination (e.g., as a result of wastewater discharges).
Nutrients - Nitrogen - Phosphorus	- Vital elements for aquatic plant and algal growth – may be limiting factors in plant growth when in short supply but in sufficient quantities they may also promote unsightly algal blooms and nuisance plant growth. Dissolved inorganic nutrient concentrations (ammoniacal nitrogen, nitrite-nitrate nitrogen and dissolved reactive phosphorus) are most relevant for predicting the potential for nuisance plant growth as they are the principal forms available to plants (i.e., soluble). Total nutrient concentrations are also relevant in surface waters, because particulate matter can settle out in quiescent areas and become biologically available to plants via mineralisation. - Nitrate may be harmful to livestock in sufficient concentrations. - Ammoniacal nitrogen is comprised of ammonium (NH_{4+}) and unionised ammonia (NH_3). Ammonia is rarely found in any significant amounts in natural waters and its presence most commonly indicates the presence of domestic, agricultural or industrial effluent. Ammonia is very soluble in water and can be toxic to aquatic life, especially fish. Toxicity is a function of both temperature and pH, with toxicity increasing with increasing water temperature and alkalinity.
Faecal Coliforms & *E. coli*	- Indicator of pollution with faecal matter, useful for determining the suitability of waters for contact recreation and stock drinking – presence in water may indicate the presence of harmful pathogens that can cause eye, ear, nose and throat infections, skin diseases, and gastrointestinal disorders - a number of parasites and pathogens can also be transmitted by contaminated water to livestock and affect their health. - *E. coli* is the most specific indicator of faecal contamination and is nearly always found in high numbers in the gut of humans and warm blooded animals. *E. coli* is the preferred microbiological indicator for faecal contamination and health effects in fresh waters.

Table A2:2 Laboratory analytical methods and detection limits employed in the RSoE monitoring programme over the reporting period (1997-2003).

Greater Wellington (Mabey Rd Laboratory)			Wairarapa Laboratory Services	
Variable	**Method**	**Detection Limit**	**Method**	**Detection Limit**
Temperature	YSI 55 Meter	0.1 ºC	YSI 59 Meter	0.1 ºC
Dissolved Oxygen	YSI 55 Meter, O_2 Probe, APHA 20th Ed. Method 4500/0G	0.1 g/m^3	YSI 59 Meter, O_2 Probe, NWSCA Method No. 38	0.1 g/m^3
Visual Clarity	Black disc	0.01 m	Black disc	0.01 m
pH	Electrometric Method APHA 20th Ed. 4500-H^+B	0.1	APHA 20th Ed. 4500-H^+B Electrometric Method	0.01
Conductivity	Orion Conductivity Meter APHA 20th Ed. Method 2510A	1.0 uS/cm	Radiometer	0.1 uS/cm
Turbidity	Nephelometric Method, APHA 20th Ed, 2130-B	0.1 NTU	Nephelometric Method, APHA 20th Ed, 2130-B	0.05 NTU
Biochemical Oxygen Demand	5 days, 20°C, Oxygen Meter, APHA 20th Ed. Method 5210B	1.0 mg/L	5 days, 20°C, Oxygen Meter, APHA 14th Ed. Method 507	0.1 mg/L
Total Organic Carbon	APHA 5310B, CASTM D2579*	0.3 mg/L	Combustion Infrared Method APHA 20th Ed. Method 5310B†	0.5 mg/L
Ammoniacal Nitrogen	Phenate Method APHA 20th Ed. 4500-NH_3 F	0.05 mg/L	Indophenol Blue Method, APHA 20th Ed. 4500-NH_3 F	0.005 mg/L
Dissolved Reactive Phosphorus	Ion Chromatography APHA 20th Ed. Method 4110BA	0.01 mg/L	Ascorbic Acid Method APHA 20th Ed. 4500-P E	0.003 mg/L
Nitrate Nitrogen	Ion Chromatography APHA (20th Ed.) Method 4110B	0.03 mg/L	Pearson Cadmium Reduction	0.002 mg/L
Total Nitrogen	Autoanalyser Wat Res 17 (1983) 1721*	0.05 mg/L	Koroleff, Alkaline Persulphate Oxidation Method, Cadmium Reduction	0.01 mg/L
Total Phosphorus	Autoanalyser Wat Res 17 (1983) 1721*	0.05 mg/L	Acid/Persulphate Digestion Ascorbic Acid Method APHA 20th Ed. 4500-P, B, E	0.003 mg/L
Faecal Coliforms	Membrane Filtration on mFC Agar, APHA 20th Ed. Method 9222D	1 cfu/100 mL	Membrane Filtration on mFC Agar, APHA 20th Ed. Method 9222D	1 cfu/100 mL
E. coli	-	-	Membrane Filtration on mFC Agar, urea substrate, APHA 20th Ed. Method 9213D	1 cfu/100 mL

* Subcontracted to ELS (Source: Adapted from Warr 2002a)
† Subcontracted to RJ Hill Laboratories

Appendix 3: Biological monitoring methods

Periphyton and macroinvertebrates can serve as good indicators of ecological change in freshwater environments. For example, changes in abundance (density) of macroinvertebrates can indicate changes in periphyton productivity, which may be indicative of increased nutrient inputs. Different macroinvertebrate species also have different tolerances to environmental factors such as dissolved oxygen, nutrients and fine sediment, such that the presence or absence of different species in an environment may indicate changes in water quality.

Key advantages of using macroinvertebrates as indicators of water quality include:

- Macroinvertebrates indicate long-term water quality conditions compared with spot physico-chemical samples which only represent water quality at time of sampling.
- Macroinvertebrates have long life spans (3 months-2 years), are relatively sedentary and easier to sample than fish.
- Macroinvertebrate analyses are a useful means of assessing the life supporting capacity of waters.
- Indices such as the Macroinvertebrate Community Index (MCI) reduce complex information on macroinvertebrate community structure into a single number.

Periphyton

Periphyton is the slimy material attached to the surfaces of rocks and other bottom substrate in rivers and streams. It is comprised of algae, diatoms, bacteria, and fungi and plays a key role in aquatic food webs because it is the main source of food for benthic invertebrates, which in turn are an important food source for fish. Excessive periphyton growths may block intake screens for water supply, and reduce the aesthetic, recreational and ecosystem values of rivers and streams.

Over the reporting period, periphyton cover was estimated by the percentage of visible mats and filaments on the stream or river bed within a 1 m^2 hoop. The assessment was made ten times across the width of the stream or river using a transect. If the stream or river width was not sufficiently long for ten samples, five samples were placed across the width of the waterway in two locations at the site. If the stream was too small for five samples an overall assessment of periphyton cover was made.

Note: Only <u>total</u> periphyton cover information was available in Greater Wellington's water quality database for RSoE sites monitored in the western Wellington region over the reporting period.

Macroinvertebrates

Macroinvertebrates are organisms that lack a backbone and are larger than 250 microns in size. Four major groups of macroinvertebrates exist; *insects* such as mayflies, caddisflies and dragonflies, *molluscs* such as snails and mussels, *crustaceans* such as freshwater shrimps and amphipods, and *oligochaetes*, aquatic worm species that live in muddy streambeds.

Macroinvertebrate sampling and processing methods have changed over time (Table A3:1). Over the majority of the reporting period, four macroinvertebrate samples were collected annually in cobbly riffle areas at or adjacent to 42 of the 51 RSoE sites.

Sampling was generally undertaken during the summer period (November-February). The timing of sampling was determined at random, although no macroinvertebrate sampling was undertaken within a week of any flood event. Flooding may cause large drifts of macroinvertebrates, carrying pollution intolerant taxa from clean upper catchment habitats to less favourable lower catchment habitats. Macroinvertebrate abundance is also greatly after a flood event.

Macroinvertebrate community structure is a product of the physical environment and water quality. Sites with similar physical characteristics were selected so that the macroinvertebrate community structure would predominantly reflect water quality influences. Before taking a sample, depth and velocity were measured using a ruler and velocity rod. Water depths were within 0.2-0.4 m and velocities between 0.6 and 1.0 m/s. If these conditions were unobtainable, a site with depth of <0.7 m and flow velocity of 0.2-1.0 m/s was selected. Substrate size was also recorded.

Once sites were selected according to the above criteria, invertebrate animals were collected in a kick net with 250 um mesh size. Four macroinvertebrate samples were taken at each site. Sample substrate was kicked for 30 seconds.

In the laboratory, macroinvertebrates were extracted from the sample under an Olympus dissecting microscope (x40). Specimens were identified to taxonomic levels specified by Stark (1985). Identifications were made according to Winterbourn (1973) for molluscs (snails) and Winterbourn and Gregson (1985) for insects.

Table A3:1: Summary of some of the key changes to macroinvertebrate sampling and processing methods in the RSoE monitoring programme to date[11].

Date	Method Details and Changes
Pre-November 1993	Western Wellington Region: Two subsamples (i.e., replicate samples) collected annually per site and results reported as a mean of the two samples. Sampling was conducted by kick-net (substrate disturbed for 30 seconds) at hard-bottomed sites only. Wairarapa: Three subsamples collected annually at each hard-bottomed site. Sampling was conducted using a surber sampler (0.1 m^2)
November 1993-1998	Western Wellington Region: The number of subsamples was increased to five, with reported results (from 1 June 2004) based on a composite result rather than a mean. Wairarapa: From 1994/1995, the number of subsamples increased to four, with sampling conducted using a kicknet.
1998/1999-2002	The number of subsamples was set to four region-wide, with results reported as a composite of the four samples. Samples were processed using coded-abundance methods.
Summer 2002/2003	The number of subsamples was reduced to three at all sites across the region, with sampling conducted using Protocol C1 of the national macroinvertebrate sampling protocols (Stark et al. 2001) for hard-bottomed streams. Samples were processed using Protocol P1 (coded-abundance) of Stark et al. (2001).
Summer 2003/2004	Review of RSoE programme (Warr 2002a) led to deletion of 13 long-term sites, the relocation of 6 sites and the addition of 18 new sites (refer Appendix 1). In addition, sampling commenced at RSoE sites with soft (muddy) substrate using Protocol C2 (Stark et al. 2001). Sample processing switched from coded abundance to fixed count methods (i.e., from Protocol P1 to Protocol P2 of Stark et al. 2001).

[11] Note that the dates are approximate only as not all changes have been clearly documented.

Calculation of Biotic Indices: MCI and SQMCI

Macroinvertebrate Community Index (MCI) values were developed by Stark (1985, 1993, 1998) for assessing organic enrichment of stony or hard-bottomed streams based on sampling macroinvertebrates from riffle (preferably) or run habitats. The MCI relies on prior allocation of scores (between 1 and 10) to taxa (usually genera) of freshwater macroinvertebrates based upon their relationship to the degree of organic enrichment. Taxa that are characteristic of un-enriched conditions score more highly than taxa that may be found predominantly in polluted conditions. The MCI is calculated as follows:-

$$\text{MCI} = \frac{\sum_{i=1}^{i=S} a_i}{S} \times 20$$

where S = the total number of taxa in the sample, and a_i is the score for the ith taxon. The MCI ranges from 0 (when no taxa are present) to 200 (when all taxa score 10 points each) although MCI scores < 40 or > 150 are rare.

The SQMCI is calculated from coded count data (individual taxa counts are assigned to one of Rare (R), Common (C), Abundant (A), Very Abundant (VA) or Very Very Abundant (VVA) abundance classes) as follows –

$$\text{SQMCI} = \sum_{i=1}^{i=S} \frac{(n_i \times a_i)}{N}$$

where S = the total number of taxa in the sample, n_i is the coded abundance for the ith scoring taxon (i.e. R=1, C=5, A=20, VA=100, VVA=500), a_i is the score for the ith taxon and N is the total of the coded abundances for the entire sample. The QMCI and SQMCI indices range from 0 to 10.

Appendix 4: Macroinvertebrate index scores

(i) MCI Scores

RSoE Site	MCI (Mean of replicate samples)	YEAR				
		1999	2000	2001	2002	2003
FB01	MCI	121	137	141	146	141
	Standard Error	12.02	5.80	4.38	2.68	2.38
FB03	MCI	117	121	132	140	140
	Standard Error	5.75	3.02	5.55	6.32	0.28
FB04	MCI	112	99	103	123	96
	Standard Error	3.58	3.90	9.90	7.89	6.40
FB06	MCI	139	141	135	129	135
	Standard Error	3.88	8.86	3.97	2.73	3.48
FB08	MCI	118	110	97	76	100
	Standard Error	1.06	8.47	6.50	4.07	1.99
FB10	MCI	102	86	91	95	79
	Standard Error	2.42	3.04	1.37	3.89	2.89
FB11	MCI	80	70	76	83	93
	Standard Error	5.43	3.62	1.77	0.78	2.65
FB12	MCI	95	93	71	81	75
	Standard Error	5.78	4.98	9.56	1.17	2.04
FB13	MCI	98	62	74	67	75
	Standard Error	5.41	7.58	2.54	2.31	0.52
FB14	MCI	97	72	94	87	91
	Standard Error	3.74	1.45	3.78	2.96	1.69
FB16	MCI	107	74	91	85	94
	Standard Error	3.08	4.09	4.54	1.48	3.40
FB18	MCI	112	101	117	100	98
	Standard Error	3.40	5.44	3.01	3.55	1.45
FB19	MCI	79	63	57	72	74
	Standard Error	4.87	5.84	1.58	0.50	5.06
FB20	MCI	81	81	79	87	81
	Standard Error	4.81	2.24	1.43	3.82	1.59
FB21	MCI	69	40	53	66	67
	Standard Error	7.41	3.69	7.97	3.01	1.13
FB22	MCI	119	138	141	137	128
	Standard Error	10.30	3.65	2.42	2.24	0.86
FB23	MCI	122	132	123	128	124
	Standard Error	4.58	4.90	5.07	2.81	0.71
FB24	MCI	99	114	107	114	114
	Standard Error	2.54	7.03	5.60	5.01	2.19
FB25	MCI	101	105	106	107	100
	Standard Error	6.79	7.43	5.48	1.95	7.86
FB26	MCI	127	132	131	139	124
	Standard Error	6.29	2.85	2.07	1.33	0.29
FB27	MCI	114	91	87	86	90
	Standard Error	0.69	4.56	2.20	1.24	1.35
FB28	MCI	115	92	87	100	101
	Standard Error	2.45	2.14	2.81	6.32	3.48
FB29	MCI	121	133	140	138	134
	Standard Error	2.62	0.97	0.42	5.72	7.54
FB31	MCI	139	138	156	144	135
	Standard Error	2.23	5.84	4.08	0.90	3.87
FB32	MCI	85	73	77	98	105
	Standard Error	4.53	1.67	3.41	4.28	2.18

RSoE Site	MCI (Mean of replicate samples)	YEAR				
		1999	2000	2001	2002	2003
FB33	MCI	82	69	62	85	94
	Standard Error	4.17	3.50	3.55	1.85	1.73
FB34	MCI	84	68	71	78	82
	Standard Error	3.61	3.02	2.57	1.74	1.69
FB35	MCI	117	136	110	120	118
	Standard Error	7.24	3.15	4.95	6.79	11.79
FB36	MCI	125	143	110	120	133
	Standard Error	3.08	6.62	3.49	3.47	4.10
FB37	MCI	109	123	111	119	126
	Standard Error	6.37	4.38	4.76	2.51	3.94
FB38	MCI	101	121	119	113	106
	Standard Error	3.51	1.25	4.02	1.75	0.81
FB39	MCI	100	119	102	106	110
	Standard Error	3.34	2.96	5.46	1.28	3.67
FB40	MCI	108	122	106	107	107
	Standard Error	2.95	1.31	2.23	2.63	1.61
FB41	MCI	107	108	97	109	99
	Standard Error	4.51	1.99	1.54	4.09	3.37
FB43	MCI	70	85	80	99	102
	Standard Error	3.78	7.34	4.69	1.94	4.18
FB44	MCI	115	102	97	90	102
	Standard Error	3.97	1.38	4.09	4.00	5.70
FB45	MCI	119	131	108	114	115
	Standard Error	2.82	4.23	3.14	2.63	2.76
FB47	MCI	135	128	125	124	144
	Standard Error	3.78	4.47	4.28	5.44	3.23
FB48	MCI	125	114	105	111	121
	Standard Error	4.75	5.22	5.21	4.31	4.58
FB49	MCI	105	99	88	95	96
	Standard Error	4.86	0.12	4.00	3.34	2.36
FB50	MCI	92	105	103	111	103
	Standard Error	2.10	3.22	3.77	4.28	7.26
FB51	MCI	110	114	107	122	116
	Standard Error	4.16	4.18	1.69	2.69	3.64

(i) SQMCI Scores

RSoE Site	SQMCI (Mean of replicate samples)	YEAR				
		1999	2000	2001	2002	2003
FB01	SQMCI	6.64	7.42	7.68	7.98	7.75
	Standard Error	0.69	0.16	0.10	0.15	0.11
FB03	SQMCI	6.86	6.18	7.38	7.44	7.73
	Standard Error	0.33	0.25	0.17	0.20	0.06
FB04	SQMCI	4.54	6.28	6.13	7.43	3.95
	Standard Error	0.43	0.32	0.42	0.08	0.17
FB06	SQMCI	7.90	7.20	7.60	6.87	6.33
	Standard Error	0.13	0.19	0.19	0.19	0.07
FB08	SQMCI	6.85	5.12	4.37	4.20	4.33
	Standard Error	0.33	0.09	0.07	0.11	0.43
FB10	SQMCI	1.63	4.06	4.01	4.64	3.51
	Standard Error	0.02	0.02	0.36	0.19	0.07
FB11	SQMCI	1.28	3.62	3.86	3.87	3.89
	Standard Error	0.05	0.04	0.06	0.15	0.10
FB12	SQMCI	1.55	3.51	2.86	2.98	2.96
	Standard Error	0.13	0.22	0.30	0.12	0.18
FB13	SQMCI	1.84	2.37	2.72	2.85	3.37
	Standard Error	0.39	0.01	0.16	0.18	0.17
FB14	SQMCI	3.78	3.28	4.55	3.79	4.42
	Standard Error	0.24	0.17	0.10	0.37	0.13
FB16	SQMCI	4.35	3.79	4.30	4.25	4.83
	Standard Error	0.13	0.29	0.16	0.13	0.20
FB18	SQMCI	5.53	5.20	6.51	6.05	6.53
	Standard Error	0.33	0.20	0.13	0.21	0.35
FB19	SQMCI	1.47	2.70	2.57	2.53	3.11
	Standard Error	0.19	0.12	0.23	0.07	0.03
FB20	SQMCI	2.28	2.99	3.75	4.07	4.11
	Standard Error	0.13	0.16	0.13	0.19	0.09
FB21	SQMCI	1.87	1.77	2.19	2.32	2.58
	Standard Error	0.28	0.12	0.11	0.06	0.10
FB22	SQMCI	7.03	7.19	7.75	7.67	6.59
	Standard Error	0.44	0.19	0.15	0.26	0.12
FB23	SQMCI	7.45	7.61	7.24	7.25	6.40
	Standard Error	0.07	0.13	0.12	0.19	0.18
FB24	SQMCI	4.19	5.33	6.58	6.59	4.56
	Standard Error	0.13	0.16	0.22	0.68	0.61
FB25	SQMCI	5.29	5.44	6.01	6.42	3.30
	Standard Error	0.52	0.28	0.31	0.50	0.10
FB26	SQMCI	7.73	6.71	7.30	6.85	6.83
	Standard Error	0.09	0.09	0.12	0.21	0.10
FB27	SQMCI	3.63	3.80	2.68	4.03	3.97
	Standard Error	0.36	0.04	0.14	0.26	0.10
FB28	SQMCI	4.15	4.31	3.89	5.20	3.88
	Standard Error	0.39	0.17	0.11	0.39	0.24
FB29	SQMCI	6.13	7.04	7.55	7.63	6.98
	Standard Error	0.12	0.19	0.11	0.31	0.29
FB31	SQMCI	7.64	7.17	7.35	7.16	7.45
	Standard Error	0.13	0.23	0.25	0.15	0.18

RSoE Site	SQMCI (Mean of replicate samples)	YEAR				
		1999	2000	2001	2002	2003
FB32	SQMCI	1.61	2.99	3.08	3.39	4.36
	Standard Error	0.07	0.11	0.15	0.21	0.06
FB33	SQMCI	2.28	2.96	2.59	3.36	4.18
	Standard Error	0.11	0.17	0.09	0.31	0.08
FB34	SQMCI	2.96	2.26	3.20	4.19	4.53
	Standard Error	0.23	0.02	0.29	0.20	0.12
FB35	SQMCI	6.51	7.18	6.21	4.57	7.26
	Standard Error	0.38	0.29	0.67	0.33	0.15
FB36	SQMCI	6.92	7.31	4.74	6.34	7.21
	Standard Error	0.14	0.20	0.49	0.32	0.40
FB37	SQMCI	5.05	6.76	4.78	7.00	6.88
	Standard Error	0.47	0.12	0.43	0.19	0.02
FB38	SQMCI	4.07	7.25	5.22	2.42	4.45
	Standard Error	0.03	0.27	0.04	0.05	0.46
FB39	SQMCI	3.73	6.28	5.65	5.54	6.16
	Standard Error	0.19	0.43	0.17	0.42	0.16
FB40	SQMCI	5.32	5.74	6.91	4.88	5.80
	Standard Error	0.20	0.18	0.29	0.51	0.02
FB41	SQMCI	3.89	4.41	3.46	4.19	4.38
	Standard Error	0.26	0.25	0.34	0.18	0.05
FB43	SQMCI	3.82	4.90	4.74	4.52	4.98
	Standard Error	0.35	0.05	0.02	0.08	0.02
FB44	SQMCI	3.72	5.33	3.69	5.95	5.24
	Standard Error	0.22	0.26	0.27	0.20	0.19
FB45	SQMCI	4.15	7.14	6.18	6.74	6.87
	Standard Error	0.12	0.24	0.27	0.28	0.07
FB47	SQMCI	7.53	6.09	7.09	6.93	6.51
	Standard Error	0.11	0.49	0.24	0.26	0.25
FB48	SQMCI	4.69	7.45	7.66	5.27	6.13
	Standard Error	0.20	0.19	0.11	0.10	0.09
FB49	SQMCI	3.42	5.56	4.01	5.29	4.88
	Standard Error	0.38	0.11	0.21	0.32	0.26
FB50	SQMCI	5.00	4.88	5.18	6.10	5.15
	Standard Error	0.26	0.15	0.14	0.16	0.23
FB51	SQMCI	4.17	6.82	3.57	5.64	5.32
	Standard Error	0.32	0.05	0.14	0.20	0.13

(iii) % EPT Scores (taxa)

RSoE Site	% EPT (taxa) (Mean of replicate samples)	YEAR				
		1999	2000	2001	2002	2003
FB01	% EPT (taxa)	58	60	71	70	63
	Standard Error	7.31	5.10	0.55	3.62	2.20
FB03	% EPT (taxa)	55	46	60	77	59
	Standard Error	2.94	1.53	7.51	6.96	0.48
FB04	% EPT (taxa)	46	24	32	45	23
	Standard Error	6.25	2.53	4.00	8.75	6.57
FB06	% EPT (taxa)	65	54	65	54	54
	Standard Error	3.25	2.06	3.76	1.60	2.11
FB08	% EPT (taxa)	39	37	16	9	5
	Standard Error	2.53	9.22	5.99	3.47	4.76
FB10	% EPT (taxa)	44	35	36	34	20
	Standard Error	3.16	3.00	3.73	3.34	4.19
FB11	% EPT (taxa)	11	0	14	15	31
	Standard Error	3.72	0.00	1.91	1.79	1.69
FB12	% EPT (taxa)	38	19	0	16	2
	Standard Error	6.28	4.77	0.00	2.27	2.22
FB13	% EPT (taxa)	26	0	3	12	6
	Standard Error	3.45	0.00	3.13	2.02	0.63
FB14	% EPT (taxa)	37	14	41	25	30
	Standard Error	2.01	4.84	2.94	5.41	0.95
FB16	% EPT (taxa)	36	25	35	31	31
	Standard Error	1.86	2.04	4.77	4.03	2.42
FB18	% EPT (taxa)	43	45	59	41	33
	Standard Error	1.63	2.67	3.60	3.12	3.33
FB19	% EPT (taxa)	15	6	0	9	7
	Standard Error	5.42	6.25	0.00	0.72	0.43
FB20	% EPT (taxa)	22	14	19	18	14
	Standard Error	3.97	7.03	2.25	1.62	3.06
FB21	% EPT (taxa)	15	6	5	0	0
	Standard Error	8.59	6.25	5.00	0.00	0.00
FB22	% EPT (taxa)	56	72	74	59	51
	Standard Error	4.67	6.64	4.95	1.79	5.18
FB23	% EPT (taxa)	53	70	49	56	48
	Standard Error	3.27	4.21	6.27	2.11	2.07
FB24	% EPT (taxa)	39	42	55	48	46
	Standard Error	3.59	5.90	3.94	3.51	2.97
FB25	% EPT (taxa)	35	47	42	38	34
	Standard Error	3.97	3.86	5.90	5.89	2.98
FB26	% EPT (taxa)	58	54	62	56	50
	Standard Error	5.25	5.91	7.26	3.82	2.31
FB27	% EPT (taxa)	51	20	28	17	25
	Standard Error	1.85	6.29	4.77	1.49	2.99
FB28	% EPT (taxa)	45	32	30	37	35
	Standard Error	1.79	2.36	0.90	3.82	0.92
FB29	% EPT (taxa)	57	63	64	65	57
	Standard Error	5.54	1.98	5.00	5.37	5.50
FB31	% EPT (taxa)	63	60	78	66	56
	Standard Error	1.10	4.17	4.19	1.77	3.38

RSoE Site	% EPT (taxa) (Mean of replicate samples)	YEAR				
		1999	2000	2001	2002	2003
FB32	% EPT (taxa)	18	10	19	28	39
	Standard Error	3.87	0.91	2.24	2.97	1.80
FB33	% EPT (taxa)	15	15	11	26	33
	Standard Error	3.21	3.15	1.39	3.04	2.50
FB34	% EPT (taxa)	21	13	17	20	21
	Standard Error	4.45	0.52	2.95	1.70	3.86
FB35	% EPT (taxa)	36	31	42	43	44
	Standard Error	6.38	2.08	2.04	4.77	9.34
FB36	% EPT (taxa)	58	65	46	50	64
	Standard Error	3.07	3.56	4.17	3.55	5.25
FB37	% EPT (taxa)	40	56	36	42	60
	Standard Error	9.51	6.39	5.21	2.96	1.39
FB38	% EPT (taxa)	44	51	54	43	45
	Standard Error	3.49	0.96	4.34	2.64	1.12
FB39	% EPT (taxa)	39	44	36	40	49
	Standard Error	1.85	3.95	5.20	2.11	3.10
FB40	% EPT (taxa)	50	53	29	43	55
	Standard Error	0.00?	2.50	2.95	2.94	2.45
FB41	% EPT (taxa)	50	51	42	52	38
	Standard Error	4.26	1.40	1.37	2.38	2.44
FB43	% EPT (taxa)	2	19	20	29	36
	Standard Error	1.67	5.84	2.54	2.99	3.92
FB44	% EPT (taxa)	56	41	38	36	44
	Standard Error	6.37	4.49	3.03	4.04	7.47
FB45	% EPT (taxa)	47	60	43	43	64
	Standard Error	3.52	3.00	4.77	3.25	1.57
FB47	% EPT (taxa)	55	69	63	61	75
	Standard Error	1.75	4.87	3.45	3.94	5.13
FB48	% EPT (taxa)	64	44	54	44	52
	Standard Error	3.16	2.57	7.62	2.13	2.38
FB49	% EPT (taxa)	43	31	30	31	39
	Standard Error	8.20	1.27	3.64	5.21	2.69
FB50	% EPT (taxa)	26	35	46	43	39
	Standard Error	5.84	2.82	5.97	3.02	5.51
FB51	% EPT (taxa)	35	49	42	49	41
	Standard Error	5.86	4.67	6.48	3.52	2.16

(iv) % EPT Scores (animals)

RSoE Site	% EPT (animals) (Mean of replicate samples)	YEAR				
		1999	2000	2001	2002	2003
FB01	% EPT (animals)	73	79	88	84	79
	Standard Error	10.12	4.83	1.35	4.46	3.17
FB03	% EPT (animals)	75	43	83	91	84
	Standard Error	7.45	6.53	3.20	2.21	1.67
FB04	% EPT (animals)	40	59	64	82	3
	Standard Error	6.62	4.60	7.54	2.87	0.39
FB06	% EPT (animals)	88	58	73	62	26
	Standard Error	4.35	6.44	6.38	5.09	1.67
FB08	% EPT (animals)	59	23	2	0	0
	Standard Error	10.24	9.94	0.77	0.15	0.03
FB10	% EPT (animals)	3	6	10	21	10
	Standard Error	0.42	0.92	2.05	1.31	2.11
FB11	% EPT (animals)	0?	0	1	1	2
	Standard Error	0.04?	0.00	0.21	0.06	0.95
FB12	% EPT (animals)	2	7	0	10	0
	Standard Error	0.65	3.39	0.00	4.26	0.33
FB13	% EPT (animals)	2	0	1	5	1
	Standard Error	1.52	0.00	0.81	1.86	0.31
FB14	% EPT (animals)	20	2	47	12	10
	Standard Error	4.30	1.06	12.36	5.02	3.15
FB16	% EPT (animals)	20	14	24	14	24
	Standard Error	4.50	3.05	5.14	4.06	9.18
FB18	% EPT (animals)	30	23	44	40	53
	Standard Error	5.10	4.69	6.84	7.13	15.36
FB19	% EPT (animals)	0?	1	0	6	4
	Standard Error	0.07?	1.43	0.00	2.77	1.31
FB20	% EPT (animals)	11	8	26	29	43
	Standard Error	0.71	3.79	10.89	12.27	13.38
FB21	% EPT (animals)	3	2	1	0	0
	Standard Error	2.01	2.08	0.89	0.00	0.00
FB22	% EPT (animals)	81	80	84	82	58
	Standard Error	5.70	9.72	5.68	4.19	4.22
FB23	% EPT (animals)	88	88	76	72	63
	Standard Error	1.95	2.46	2.97	7.40	4.46
FB24	% EPT (animals)	33	45	75	71	40
	Standard Error	2.15	2.67	5.33	13.04	9.74
FB25	% EPT (animals)	53	44	47	63	9
	Standard Error	6.99	9.53	6.73	9.66	1.76
FB26	% EPT (animals)	91	43	75	42	74
	Standard Error	2.62	6.23	8.37	8.78	2.14
FB27	% EPT (animals)	25	9	5	10	4
	Standard Error	3.26	2.54	1.58	3.63	2.05
FB28	% EPT (animals)	30	19	18	35	22
	Standard Error	5.39	3.48	0.58	10.26	8.53
FB29	% EPT (animals)	67	74	83	87	82
	Standard Error	1.53	6.86	1.61	3.76	4.21
FB31	% EPT (animals)	82	71	71	74	64
	Standard Error	1.65	6.55	7.45	4.36	7.17

RSoE Site	% EPT (animals) (Mean of replicate samples)	YEAR				
		1999	2000	2001	2002	2003
FB32	% EPT (animals)	1	17	7	9	28
	Standard Error	0.29	4.10	2.49	0.49	10.62
FB33	% EPT (animals)	2	3	5	14	43
	Standard Error	0.74	0.69	1.88	3.53	15.43
FB34	% EPT (animals)	16	3	31	32	38
	Standard Error	4.25	0.88	11.87	9.27	10.64
FB35	% EPT (animals)	48	57	57	21	72
	Standard Error	14.13	8.20	9.97	5.89	6.70
FB36	% EPT (animals)	64	64	38	63	56
	Standard Error	4.88	6.94	6.80	5.26	18.57
FB37	% EPT (animals)	22	53	44	80	73
	Standard Error	11.55	3.97	9.19	3.14	0.20
FB38	% EPT (animals)	4	75	48	4	27
	Standard Error	1.35	5.46	0.97	0.78	4.74
FB39	% EPT (animals)	15	48	31	32	14
	Standard Error	3.88	8.65	5.04	7.05	3.78
FB40	% EPT (animals)	10	28	75	21	29
	Standard Error	2.73	6.65	6.72	7.76	0.82
FB41	% EPT (animals)	31	32	20	21	39
	Standard Error	8.05	3.45	4.74	3.23	5.74
FB43	% EPT (animals)	0?	1	0?	12	8
	Standard Error	0.40?	0.48	0.04?	1.35	1.82
FB44	% EPT (animals)	18	25	14	29	39
	Standard Error	4.22	6.80	1.82	7.93	9.86
FB45	% EPT (animals)	23	76	55	67	53
	Standard Error	1.27	5.64	6.16	5.73	0.94
FB47	% EPT (animals)	84	61	78	76	65
	Standard Error	2.02	7.47	4.76	4.84	5.00
FB48	% EPT (animals)	37	85	95	39	24
	Standard Error	3.74	2.73	1.72	1.43	3.21
FB49	% EPT (animals)	6	15	13	13	8
	Standard Error	1.55	3.00	3.41	1.18	1.67
FB50	% EPT (animals)	4	16	39	38	9
	Standard Error	1.57	1.55	8.75	2.45	1.82
FB51	% EPT (animals)	19	73	19	35	12
	Standard Error	5.88	5.35	3.84	7.37	3.62

Appendix 5: Macroinvertebrate index correlations

Kindly performed by John Stark, Cawthron Institute.

(1) Spearman Rank Order Correlations (using mean index values for 1999-2003 data)

	n	**Spearman**	**t(N-2)**	***p***
MCI & SQMCI	42	0.960133	21.72257	0.000000
MCI & % EPT (taxa)	42	0.963536	22.77443	0.000000
MCI & % EPT (animals)	42	0.934365	16.58479	0.000000
SQMCI & % EPT (taxa)	42	0.917187	14.55812	0.000000
SQMCI & % EPT (animals)	42	0.934041	16.53964	0.000000
% EPT (taxa) & % EPT (animals)	42	0.930476	16.06329	0.000000

(2) Pearson Linear Correlations (using mean index values for 1999-2003 data)

	MCI	**SQMCI**	**% EPT (taxa)**	**% EPT (animals)**
MCI	1.0000	0.9623	0.9617	0.9201
	n=42	*n*=42	*n*=42	*n*=42
	p= ---	p=0.00	p=0.00	p=0.00
SQMCI	0.9623	1.0000	0.9250	0.9297
	n=42	*n*=42	*n*=42	*n*=42
	p=0.00	p= ---	p=0.00	p=0.00
% EPT (taxa)	0.9617	0.9250	1.0000	0.9028
	n=42	*n*=42	*n*=42	*n*=42
	p=0.00	p=0.00	p= ---	p=0.00
% EPT (animals)	0.9201	0.9297	0.9028	1.0000
	n=42	*n*=42	*n*=42	*n*=42
	p=0.00	p=0.00	p=0.00	p= ---

- All analyses performed using STATISTICA 7.1.
- Marked correlations are significant at $p < 0.05$.

Appendix 6: Statistical methods for temporal trend analyses

Temporal trend analyses were performed using the Seasonal Kendall trend test on raw and, where available, flow-adjusted water quality records in the WQSTAT PLUS for Windows statistical programme. The Seasonal Kendall trend test and flow-adjustment are outlined below.

Seasonal Kendall Trend Analysis

The Seasonal Kendall trend test is a non-parametric statistical method used in the analysis of water quality trends. For monthly samples the seasonal Kendall Sen slope estimator is the median of all possible combinations of slopes for each of the months of the year. For example, in a 4 year record there will be 4 observations for January. There will thus be 10 (4+3+2+1) possible combinations of all pairs of January observations resulting in 10 January slopes. This will also be the case for each of the other 11 months. The seasonal Kendall Sen slope estimator is computed as the median of all 120 (=10*12) individual slopes. This means that seasonality is accounted for, because the results for all Januarys are compared one with another, but they are not compared with those from the other months. The Seasonal Kendall trend test assesses whether the trend slope is significant or not (i.e., the probability of the observed trend being due to chance). This is often called a *p* value. It is calculated by comparing the total number of increasing monthly slopes with the total number of decreasing slopes. If the net result is close to zero the *p* value will be large, so the slope can be regarded as being due to chance; conversely, a large difference between the numbers of increasing and decreasing slopes produces a low *p* value, meaning the slope is unlikely to be due to chance. A *p* value of 5% or less is conventionally regarded as indicating that a trend is statistically significant (i.e., unlikely to be due to chance).

Flow adjustment

Flow adjustment allows the user to relate river or stream flow to various constituents and to remove flow effects prior to further statistical analysis. For water quality variables which are closely related to flow, an apparent trend in quality could be caused by a change in flow. By flow adjusting before trend analysis, the user can remove flow effects and determine the magnitude and statistical significance of trends which are not explained by flow.

Flow adjustment was performed for 14 sites (Table A6:1) using WQSTAT PLUS. For simplicity, the following log – log relationship between water quality and flow is assumed:

Log Concentration = b(log flow) +a

WQSTAT PLUS uses linear regression to estimate the slope and intercept of the line above. Then from each water quality observation (log concentration), the corresponding prediction based on flow, b(log flow)+ a is subtracted, producing a series of residuals with a mean of zero. To each residual, the mean of the original log concentrations series is added, producing series of residuals with a mean of zero. To each residual, the mean of the original log concentrations series is added, producing a flow – adjusted series of log concentrations which has the same mean as the original. Next, the antilogs of the log concentrations are found, and a final correction is made so that the resulting series in original concentration units will have the same mean as the original series of observations.

Table A6:1: List of RSoE monitoring sites with water quality records analysed for both raw and flow-adjusted trends. Flow adjustments were made using the ***instantaneous*** flow at the time of sampling[12].

Site No.	Site Name	Flow Recorder Location
FB01	Waitohu S at Water Supply Intake	Water Supply Intake
FB03	Otaki R at Pukehinau	Pukehinau
FB22	Hutt R at Te Marua Water Intake	Te Marua
FB24	Hutt R opp. Manor Park G.C.	D/s - Taita Gorge
FB28	Mangaroa R at Te Marua	Te Marua
FB29	Akatarawa R u/s Hutt R confl.	Akatarawa Cemetery
FB30	Waiwhetu S at Wainui Hill Br	U/s - White Lines East
FB31	Wainuiomata R at Manuka Track	Manuka Track
FB32	Wainuiomata R at L. Wood Pk	Leonard Wood Park
FB33	Wainuiomata R at Golf Course	U/s - Leonard Wood Park
FB36	Ruamahanga R at Mt Bruce	State Highway 2
FB40	Ruamahanga R at Waihenga Br	Waihenga
FB42	Whangaehu R at Waihi	Waihi
FB47	Waiohine R at Gorge	Waiohine Gorge

[12] If no instantaneous flow was available, the sampling result was removed from the data set.

Appendix 7: Trend analyses performed by Death & Death (2005)

Death and Death (2005) performed temporal trend analyses on Greater Wellington's water quality and macroinvertebrate monitoring records[13].

Physico-chemical and microbiological trend analyses

For the physico-chemical water quality trend analyses, Death and Death (2005) utilised the full data record available for each RSoE site (i.e., as far back as 1987 in some cases). Following completion of this work, errors were discovered in Greater Wellington's water quality database. Consequently, the results of trend analyses presented in Death and Death (2005) were not used in this report. Analyses were re-run with corrected data over a shorter time period (1 September 1997 to 31 August 2003 inclusive) to focus on more recent trends and align with the reporting period used for assessing water quality state.

Macroinvertebrate trend analyses

Death and Death (2005) undertook trend analyses on macroinvertebrate data for 42 RSoE sites monitored over 1999 to 2003 or 1999 to 2004 inclusive. Six sites were relocated upstream during the reporting period, following the RSoE programme review by Warr (2002a). The relocation distances varied from 0.4 km to 7 km (Table A7.1). No allowance was made for potential differences in the data from the new sites; data collected from the new sites in 2004 was included with the original site data for trend analysis. A summary of the trends in macroinvertebrate health reported by Death and Death (2005) is summarised in Table A7.2.

Table A7.1: RSoE sites relocated upstream in August 2003.

Site No.	Site Name	New Site and Site No.	Approximate Relocation Distance
FB01	Waitohu S at Water Supply Intake	Waitohu S at Forest Park (RS03)	1.3 km upstream
FB06	Waikanae R at Reikorangi Br	Waikanae R at Mangaone Walkway (RS09)	7 km upstream
FB08	Waikanae R at Oxbow Boat Ramp	Waikanae R at Greenaway Rd (RS10)	2.1 km upstream
FB10	Horokiri S at Ongly	Horokiri S at Snodgrass (RS13)	1 km upstream
FB25	Hutt R u/s Melling Br	Hutt R at Boulcott (RS22)	0.4 km upstream
FB36	Ruamahanga R at Mt Bruce	Ruamahanga R at McLays (RS31)	5 km upstream

[13] Note: Where RSoE sites were relocated in August 2003, Death and Death (2005) used the new site name, rather than the name of the original site against which most of the data relates.

Table A7.2: Summary of linear trends in macroinvertebrate indices examined at 42 RSoE sites by Death and Death (2005) using Spearman rank correlations.

Site No.	Site Name	MCI		SQMCI		% EPT (taxa)		% EPT (animals)	
		Spearman correlation	Trend	Spearman correlation	Trend	Spearman correlation	Trend	Spearman correlation	Trend
FB01	Waitohu S at Water Supply Intake	0.37	Steady	0.60	Steady	0.77	Improving	0.49	Steady
FB03	Otaki R at Pukehinau	0.94	Improving	0.60	Steady	0.67	Steady	0.26	Steady
FB04	Otaki R at Mouth	0.14	Steady	0.37	Steady	-0.31	Steady	0.31	Steady
FB06	Waikanae R at Reikorangi Br	-0.77	Declining	-0.54	Steady	0.2	Steady	-0.26	Steady
FB08	Waikanae R at Oxbow Boat Ramp	0.03	Steady	-0.09	Steady	-0.14	Steady	-0.14	Steady
FB10	Horokiri S at Ongly	0.09	Steady	0.6	Steady	-0.09	Steady	0.94	Improving
FB11	Pauatahanui S at Elmwood Br	0.83	Improving	1	Improving	0.94	Improving	0.89	Improving
FB12	Porirua S at Glenside	0.03	Steady	0.60	Steady	0.03	Steady	0.37	Steady
FB13	Porirua S at Wall Pk (Milk Station)	0.37	Steady	1.0	Improving	0.37	Steady	0.54	Steady
FB14	Ohariu S 50m u/s Makara Stream	-0.3	Steady	0.6	Steady	-0.1	Steady	-0.2	Steady
FB16	Makara S at Kennels	0.37	Steady	-0.26	Steady	0.26	Steady	-0.37	Steady
FB18	Karori S d/s Sth Makara Stream	-0.7	Steady	0.8	Improving	-0.6	Steady	0.8	Improving
FB19	Owhiro S at Mouth	-0.1	Steady	0.6	Steady	-0.2	Steady	0.6	Steady
FB20	Kaiwharawhara S at Ngaio Gorge	0.71	Steady	1.0	Improving	0.20	Steady	0.60	Steady
FB21	Ngauranga S 400m u/s Mouth	0.00	Steady	0.90	Improving	-0.97	Declining	-0.97	Declining
FB22	Hutt R at Te Marua Water Intake	-0.08	Steady	0.37	Steady	-0.14	Steady	0.31	Steady
FB23	Hutt R at Birchville Canoe Club	0.30	Steady	-0.80	Declining	-0.50	Steady	-0.90	Declining
FB24	Hutt R opp. Manor Park G.C.	0.83	Improving	0.66	Steady	0.77	Improving	0.60	Steady
FB25	Hutt R u/s of Melling Br	0.43	Steady	0.43	Steady	0.2	Steady	0.26	Steady
FB26	Pakuratahi R 50m d/s Farm Ck	0.37	Steady	0.20	Steady	0.14	Steady	-0.14	Steady
FB27	Mangaroa R at Kalcoolies Cnr	-0.70	Steady	0.60	Declining	-0.50	Steady	-0.70	Declining
FB28	Mangaroa R at Te Marua	0.37	Steady	0.26	Steady	0.31	Steady	0.49	Steady
FB29	Akatarawa R u/s Hutt R confl.	0.20	Steady	0.66	Steady	0.66	Steady	0.83	Improving
FB31	Wainuiomata R at Manuka Track	-0.54	Steady	0.26	Steady	0.14	Steady	0.09	Steady
FB32	Wainuiomata R at L. Wood Pk	0.70	Steady	1.00	Improving	0.90	Improving	0.70	Steady
FB33	Wainuiomata R at Golf Course	0.60	Steady	0.90	Improving	0.60	Steady	1.00	Improving
FB34	Wainuiomata R u/s of White Br	0.43	Steady	0.94	Improving	0.67	Steady	0.31	Steady
FB35	Orongorongo R at Orongo. Stn	-0.20	Steady	0.49	Steady	0.31	Steady	0.60	Steady
FB36	Ruamahanga R at Mt Bruce	-0.31	Steady	-0.31	Steady	0.09	Steady	-0.82	Declining
FB37	Ruamahanga R at Dble Bridges	0.70	Steady	0.60	Steady	0.50	Steady	0.80	Improving
FB38	Ruamahanga R at Te Ore Ore	0.03	Steady	0.31	Steady	-0.49	Steady	0.09	Steady
FB39	Ruamahanga R at Gladstone Br	0.66	Steady	0.60	Steady	0.71	Steady	0.26	Steady
FB40	Ruamahanga R at Waihenga Br	-0.60	Steady	0.20	Steady	0.20	Steady	0.50	Steady
FB41	Kopuaranga S at Stewarts	0.37	Steady	0.54	Steady	-0.37	Steady	0.54	Steady
FB43	Whangaehu R 250 u/s confl.	0.94	Improving	0.77	Improving	0.66	Steady	0.09	Steady
FB44	Waipoua R at Colombo Rd Br	0.03	Steady	0.60	Steady	-0.09	Steady	0.83	Improving
FB45	Waingawa R at South Rd	-0.54	Steady	0.67	Steady	-0.37	Steady	0.49	Steady
FB47	Waiohine R at Gorge	0.09	Steady	0.20	Steady	0.71	Steady	0.20	Steady
FB48	Waiohine R at Bicknells	-0.03	Steady	0.14	Steady	-0.26	Steady	-0.14	Steady
FB49	Mangatarere R at SH2	0.09	Steady	0.60	Steady	0.26	Steady	0.43	Steady
FB50	Huangarua R at Ponatahi Br	0.71	Steady	0.66	Steady	0.60	Steady	0.31	Steady
FB51	Tauherenikau R at Websters	0.77	Improving	0.49	Steady	0.49	Steady	0.14	Steady

Appendix 8: Results of temporal trend analyses

Site No.	Variable	Slope	Z	n	p	Comments
FB01	Turbidity	-0.02031	-0.7244	70	NS	
	Visual Clarity	0.07068	0.9196	68	NS	
	Total N	-0.01197	-0.4695	23	NS	
	Total P	-0.0009147	-0.4774	23	NS	
	Diss. Reactive P	0	0.1124	70	NS	Affected by non-detect values
	Nitrate N	-0.002549	-2.006	70	<0.05	
	Ammoniacal N	0	0	70	NS	All non-detect values
	BOD	0	-0.461	45	NS	
	Total Org. Carbon	-0.3476	-1.408	23	<0.2	
	Conductivity	1.647	2.102	59	<0.05	Break in data record
	Temperature	-0.1008	-0.7225	70	NS	
	pH	0	-1.935	70	<0.1	Even scatter above & below trend line
	Faecal Coliforms	-3.008	-1.484	70	<0.2	
	Diss. Ox (% sat)	-0.09172	-0.421	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB01	Turbidity	-0.04192	-1.384	67	<0.2	
Flow-adjusted data	Visual Clarity	0.04564	0.4652	65	NS	
	Total N					Insufficient data for trend analysis
	Total P					Insufficient data for trend analysis
	Diss. Reactive P	0.0000	-0.06387	67	NS	
	Nitrate N	-0.002487	-1.767	67	<0.1	
	Ammoniacal N	0	0.3638	67	NS	All non-detect values
	BOD	0.02742	1.286	45	<0.2	
	Total Org. Carbon					Insufficient data for trend analysis
	Conductivity	0.6245	1.346	59	<0.2	Break in data record
	Temperature	-0.1269	-1.554	67	<0.2	
	pH	-0.03853	-3.002	67	<0.2	
	Faecal Coliforms	-2.965	-1.384	67	<0.2	
	Diss. Ox (% sat)	-0.1528	-0.4471	67	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB02	Turbidity	-1.26	-4.871	71	<0.05	
	Visual Clarity	0.04214	3.052	70	<0.05	
	Total N	-0.05041	-0.2754	26	NS	
	Total P	0.008745	0.8257	26	NS	
	Diss. Reactive P	0	-1.812	71	<0.1	
	Nitrate N	-0.0496	-2.169	71	<0.05	
	Ammoniacal N	-0.02589	-5.572	71	<0.05	
	BOD	-0.3703	-4.259	45	<0.05	
	Total Org. Carbon	0.3507	0.7344	26	NS	
	Conductivity	2.115	0.4028	31	NS	Break in data record
	Temperature	-0.08815	-0.4127	71	NS	
	pH	0	-2.18	71	<0.05	Even scatter above & below trend line
	Faecal Coliforms	-79.06	-3.597	71	<0.05	
	Diss. Ox (% sat)	0.1955	0.2354	71	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
FB03	Turbidity	-0.2418	-1.906	70	<0.1	
	Visual Clarity	0.2814	1.883	70	<0.1	
	Total N	0.005136	0.6575	26	NS	
	Total P	-0.00262	-2.334	26	<0.05	
	Diss. Reactive P	0.0009965	6.238	70	<0.05	Affected by non-detect values
	Nitrate N	-0.002559	-2.287	70	<0.05	
	Ammoniacal N	0.005161	6.953	70	<0.05	Affected by non-detect values
	BOD	0.1671	5.296	44	<0.05	Affected by non-detect values
	Total Org. Carbon	0	0	26	NS	
	Conductivity	0.3318	0.5973	59	NS	Break in data record
	Temperature	-0.04761	-0.5819	70	NS	
	pH	-0.02597	-2.409	70	<0.05	
	Faecal Coliforms	-0.3904	-1.217	70	NS	
	Diss. Ox (% sat)	0.1404	0.4813	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FBO3	Turbidity	-0.1238	-1.262	70	NS	
Flow-adjusted data	Visual Clarity	0.1218	1.502	70	0.2	
	Total N	0.005238	0.4564	26	NS	
	Total P	-0.001152	-1.917	26	<0.1	
	Diss. Reactive P	0.0009174	5.148	70	<0.05	Affected by non-detect values
	Nitrate N	-0.001665	-1.502	70	0.2	
	Ammoniacal N	0.005258	6.189	70	<0.05	Affected by non-detect values
	BOD	0.1549	4.937	44	<0.05	Affected by non-detect values
	Total Org. Carbon	0.0939	0.8216	26	NS	
	Conductivity	0.3584	1.444	59	0.2	Break in data record
	Temperature	-0.06951	-0.8613	70	NS	
	pH	-0.03542	-3.465	70	<0.05	
	Faecal Coliforms	-0.256	-1.102	70	NS	
	Diss. Ox (% sat)	0.1607	0.5007	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB04	Turbidity	-0.2113	-1.081	70	NS	
	Visual Clarity	0.1586	1.839	70	<0.1	
	Total N	-0.01219	-0.9263	26	NS	
	Total P	-0.001374	-1.031	26	NS	
	Diss. Reactive P	0	5.846	70	<0.05	Affected by non-detect values
	Nitrate N	-0.003347	-1.519	70	<0.2	
	Ammoniacal N	0.005971	6.767	70	<0.05	Affected by non-detect values
	BOD	0.1661	4.683	44	<0.05	Affected by non-detect values
	Total Org. Carbon	-0.8919	-0.7406	26	NS	
	Conductivity	1.225	1.723	59	<0.1	Break in data record
	Temperature	-0.04504	-0.28	70	NS	
	pH	0	-0.559	70	NS	
	Faecal Coliforms	-6.002	-1.942	70	<0.1	
	Diss. Ox (% sat)	0.6453	1.54	70	<0.1	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB05	Turbidity	-1.027	-3.969	70	<0.05	
	Visual Clarity	0.04831	2.788	70	<0.05	
	Total N	-0.2957	-1.004	26	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Total P	-0.001795	-0.2739	26	NS	
	Diss. Reactive P	0	-0.6804	70	NS	
	Nitrate N	0.02169	0.3824	70	NS	
	Ammoniacal N	-0.02485	-5.696	70	<0.05	
	BOD	-0.2619	-2.379	44	<0.05	
	Total Org. Carbon	-1.073	-2.113	26	<0.05	
	Conductivity	2.951	1.368	59	<0.2	Break in data record
	Temperature	-0.02686	-0.1404	70	NS	
	pH	-0.01999	-2.167	70	<0.05	
	Faecal Coliforms	-348.7	-5.538	70	<0.05	
	Diss. Ox (% sat)	-1.414	-1.462	70	<0.2	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB06	Turbidity	-0.0461	-2.432	72	<0.05	
	Visual Clarity	0.01977	0.1767	71	NS	
	Total N	-0.06397	-1.187	26	NS	
	Total P	-0.005807	-2.137	26	<0.05	
	Diss. Reactive P	0	2.886	72	<0.05	Affected by non-detect values
	Nitrate N	-0.006621	-1.393	72	<0.2	
	Ammoniacal N	0.005953	7.07	72	<0.05	Affected by non-detect values
	BOD	0.165	4.541	47	<0.05	Affected by non-detect values
	Total Org. Carbon	-0.4318	-2.737	25	<0.05	
	Conductivity	1.65	3.263	61	<0.05	Break in data record
	Temperature	-0.04875	-0.2311	72	NS	
	pH	0	-0.03937	72	NS	
	Faecal Coliforms	-8.986	-1.772	72	<0.1	
	Diss. Ox (% sat)	0.9795	3.139	72	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB07	Turbidity	0	-0.0774	72	NS	
	Visual Clarity	0.003363	0.3856	72	NS	
	Total N	-1.665	-3.569	26	<0.05	
	Total P	-0.2945	-4.29	26	<0.05	
	Diss. Reactive P	-0.02768	-3.492	72	<0.05	
	Nitrate N	-0.03113	-1.908	72	<0.1	
	Ammoniacal N	-0.1092	-2.348	72	<0.05	
	BOD	0.4278	2.237	47	<0.05	
	Total Org. Carbon	-3.712	-1.984	25	<0.05	
	Conductivity	5.628	1.307	61	<0.2	Break in data record
	Temperature	-0.02001	-0.1734	72	NS	
	pH	0	-1.093	72	NS	
	Faecal Coliforms	-187.2	-4.798	72	<0.05	
	Diss. Ox (% sat)	-0.7539	-0.885	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB08	Turbidity	0	0	72	NS	
	Visual Clarity	0.07388	1.309	72	<0.2	
	Total N	0.008099	0.09175	26	NS	
	Total P	-0.01487	-0.2772	26	NS	
	Diss. Reactive P	0.003349	3.854	61	NS	
	Nitrate N	0.02629	1.814	65	<0.1	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Ammoniacal N	0.006105	2.524	72	<0.05	
	BOD	0.2339	3.853	47	<0.05	Affected by non-detect values?
	Total Org. Carbon	0.09216	0	25	NS	
	Conductivity	155.4	1.713	60	<0.1	Break in data record
	Temperature	0.1479	0.7702	72	NS	
	pH	0	-1.533	72	<0.2	
	Faecal Coliforms	7.893	0.2889	72	NS	
	Diss. Ox (% sat)	-0.4046	-0.4039	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB09	Turbidity	-0.189	-0.5013	72	NS	
	Visual Clarity	0.003947	0.521	72	NS	
	Total N	1.358	2.465	26	<0.05	
	Total P	1.139	3.012	26	<0.05	
	Diss. Reactive P	0.08466	5.155	64	<0.05	Huge increase from 2001/2002
	Nitrate N	0.2589	3.048	68	<0.05	
	Ammoniacal N	-0.01877	-1.002	72	NS	
	BOD	0	0	47	NS	
	Total Org. Carbon	-1.655	-1.388	25	<0.2	
	Conductivity	18.64	1.675	61	<0.1	Break in data record
	Temperature	0.1581	0.9432	72	NS	
	pH	0	-1.107	72	NS	
	Faecal Coliforms	22.22	0.3083	72	NS	
	Diss. Ox (% sat)	-0.004581	0	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB10	Turbidity	0	0	72	NS	
	Visual Clarity	0.01874	0.1154	72	NS	
	Total N	-0.3577	-2.83	26	<0.05	
	Total P	-0.002406	-1.33	26	<0.2	
	Diss. Reactive P	0	-0.1383	71	NS	
	Nitrate N	-0.01664	-1.514	71	<0.2	
	Ammoniacal N	0	0	72	NS	
	BOD	0	0.09704	45	NS	
	Total Org. Carbon	-0.344	-2.69	26	<0.05	
	Conductivity	1.688	2.595	61	<0.05	Break in data record
	Temperature	-0.06096	-0.7143	72	NS	
	pH	0	-0.764	72	NS	
	Faecal Coliforms	7.114	0.4237	72	NS	
	Diss. Ox (% sat)	0.634	1.27	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB11	Turbidity	-0.2004	-2.081	72	<0.05	
	Visual Clarity	0.08844	1.404	69	<0.2	
	Total N	-0.1834	-2.654	26	<0.05	
	Total P	0.000891	0.1847	26	NS	
	Diss. Reactive P	0	4.541	71	<0.05	Affected by non-detect values
	Nitrate N	-0.002456	-0.315	71	NS	
	Ammoniacal N	0.005094	6.497	72	<0.05	Affected by non-detect values
	BOD	0.1661	4.135	45	<0.05	Affected by non-detect values
	Total Org. Carbon	-0.365	-1.569	26	<0.2	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Conductivity	3.357	2.963	61	<0.05	Break in data record
	Temperature	-0.132	-1.041	72	NS	
	pH	0	-0.7235	72	NS	
	Faecal Coliforms	-75.15	-2.465	72	<0.05	
	Diss. Ox (% sat)	0.4887	1.54	72	<0.2	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB12	Turbidity	-0.03719	-0.6366	72	NS	
	Visual Clarity	0.03499	0.6158	72	NS	
	Total N	-0.4239	-1.922	26	<0.1	
	Total P	-0.00136	-0.09129	26	NS	
	Diss. Reactive P	0	1.778	71	<0.1	Not a real trend?
	Nitrate N	-0.02158	-0.9057	71	NS	
	Ammoniacal N	0.005973	6.557	72	<0.05	Affected by non-detect values
	BOD	0.1661	2.982	45	<0.05	Affected by non-detect values?
	Total Org. Carbon	-0.1085	-0.5508	26	NS	
	Conductivity	1.921	1.209	61	NS	Break in data record
	Temperature	0.04424	0.3659	72	NS	
	pH	0	0.4871	72	NS	
	Faecal Coliforms	-132.9	-2.694	72	<0.05	
	Diss. Ox (% sat)	0.6555	1.135	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB13	Turbidity	-0.05037	-0.5773	72	NS	
	Visual Clarity	0.04896	0.9408	72	NS	
	Total N	-0.496	-2.198	26	<0.05	
	Total P	-0.002816	-0.3675	26	NS	
	Diss. Reactive P	0	2.279	71	<0.05	Affected by non-detect values
	Nitrate N	0.003496	0.5715	71	NS	
	Ammoniacal N	0.006158	6.257	72	<0.05	Affected by non-detect values
	BOD	0.1667	3.123	45	<0.05	Affected by non-detect values
	Total Org. Carbon	-0.1022	-0.8036	25	NS	
	Conductivity	1.592	1.571	61	<0.2	Break in data record
	Temperature	0.02931	0.2115	72	NS	
	pH	0	0.3885	72	NS	
	Faecal Coliforms	-128.7	-2.171	72	<0.05	
	Diss. Ox (% sat)	0.776	1.517	72	<0.2	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB14	Turbidity	0	0	72	NS	
	Visual Clarity	0.03942	0.6933	72	NS	
	Total N	-0.2238	-1.294	25	<0.2	
	Total P	0.01319	1.785	25	<0.1	
	Diss. Reactive P	0	0.9813	72	NS	
	Nitrate N	0.007311	0.7673	35	NS	
	Ammoniacal N	0.005092	6.327	72	<0.05	Affected by non-detect values
	BOD	0.06216	2.299	47	<0.05	Affected by non-detect values?
	Total Org. Carbon	0.0976	0.1046	24	NS	
	Conductivity	2.791	2.148	61	<0.05	Break in data record
	Temperature	0.1436	0.6936	72	NS	
	pH	0.01992	1.456	72	<0.2	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Faecal Coliforms	-8.895	-0.4629	72	NS	
	Diss. Ox (% sat)	2.112	4.715	72	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB15	Turbidity	-0.02023	-0.4834	72	NS	
	Visual Clarity	-0.005519	-0.09624	72	NS	
	Total N	-0.08548	-1.388	25	<0.2	
	Total P	0.003931	0.9918	25	NS	
	Diss. Reactive P	0	2.03	72	<0.05	Not a real trend?
	Nitrate N	-0.009886	-1.178	72	NS	
	Ammoniacal N	0.00579	7.07	72	<0.05	Affected by non-detect values
	BOD	0.1661	5.396	47	<0.05	Affected by non-detect values
	Total Org. Carbon	0.1455	1.053	24	NS	
	Conductivity	0.6855	0.4938	61	NS	Break in data record
	Temperature	0.1041	0.982	72	NS	
	pH	0	0.9052	72	NS	
	Faecal Coliforms	-82.14	-1.754	72	<0.1	
	Diss. Ox (% sat)	0.7849	1.79	72	<0.1	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB16	Turbidity	-0.2918	-1.908	72	<0.1	
	Visual Clarity	0.09187	2.33	72	<0.05	
	Total N	-0.1198	-0.9947	25	NS	
	Total P	0.009216	1.393	25	0.2	
	Diss. Reactive P	0	1.14	72	NS	
	Nitrate N	-0.002222	-0.4256	72	NS	
	Ammoniacal N	0	-2.038	72	<0.05	Not a real trend?
	BOD	0	2.177	47	<0.05	Affected by non-detect values
	Total Org. Carbon	0.3968	1.492	25	<0.2	
	Conductivity	1.791	1.53	61	<0.2	Break in data record
	Temperature	0.04911	0.2892	72	NS	
	pH	0	0.6559	35	NS	
	Faecal Coliforms	-134.8	-2.679	72	<0.05	
	Diss. Ox (% sat)	1.022	0.4625	35	NS	Break in data record
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB17	Turbidity	0.004836	0.2897	72	NS	
	Visual Clarity	-0.1199	-1.256	71	NS	
	Total N	-0.198	-1.298	25	<0.2	
	Total P	0.01404	1.995	25	<0.05	
	Diss. Reactive P	0	2.186	72	<0.05	Not a real trend?
	Nitrate N	-0.1035	-5.255	72	<0.05	
	Ammoniacal N	0.006214	6.769	72	<0.05	Affected by non-detect values
	BOD	0.1658	4.495	47	<0.05	Affected by non-detect values
	Total Org. Carbon	0.4011	1.692	25	<0.1	
	Conductivity	-3.098	-3.098	61	<0.05	Break in data record
	Temperature	-0.171	-1.832	72	<0.1	
	pH	-0.04008	-3.648	72	<0.05	
	Faecal Coliforms	121.9	0.981	72	NS	
	Diss. Ox (% sat)	0.03227	0.1541	72	NS	

Site No.	Variable	Slope	Z	n	p	Comments
FB18	Turbidity	0.1032	2.458	72	<0.05	
	Visual Clarity	-0.2606	-3.463	72	<0.05	
	Total N	-0.1973	-2.579	25	<0.05	
	Total P	-0.006402	-0.7934	25	NS	
	Diss. Reactive P	0	0.03994	72	NS	
	Nitrate N	-0.01042	-1.063	72	NS	
	Ammoniacal N	0.006214	6.85	72	<0.05	Affected by non-detect values
	BOD	0.1661	5.238	47	<0.05	Affected by non-detect values
	Total Org. Carbon	0.111	0.8005	25	NS	
	Conductivity	0.7048	0.7659	61	NS	Break in data record
	Temperature	-0.101	-0.867	72	NS	
	pH	-0.03249	-2.639	72	<0.05	
	Faecal Coliforms	39.4	1.37	72	<0.2	
	Diss. Ox (% sat)	0.03553	0.1348	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB19	Turbidity	-0.02601	-0.3085	72	NS	
	Visual Clarity	0.1096	1.158	71	NS	
	Total N	-0.1944	-1.734	26	<0.1	
	Total P	-0.003504	-0.2766	26	NS	
	Diss. Reactive P	0.001637	5.213	72	<0.05	Affected by non-detect values?
	Nitrate N	-0.1037	-3.597	72	<0.05	
	Ammoniacal N	0	3.023	72	<0.05	Affected by non-detect values
	BOD	0.1667	2.259	47	<0.05	Affected by non-detect values
	Total Org. Carbon	0.1626	0.3663	26	NS	
	Conductivity	-1.753	-0.4439	61	NS	Break in data record
	Temperature	-0.02974	-0.2311	72	NS	
	pH	0	0.4553	72	NS	
	Faecal Coliforms	-91.41	-1.579	72	<0.2	
	Diss. Ox (% sat)	1.266	2.483	72	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB20	Turbidity	0.02665	1.063	72	NS	
	Visual Clarity	-0.1583	-1.393	71	<0.2	
	Total N	-0.1796	-2.02	26	<0.05	
	Total P	0.003125	0.3682	26	NS	
	Diss. Reactive P	0	2.302	72	<0.05	No real trend present
	Nitrate N	-0.02222	-1.249	72	NS	
	Ammoniacal N	0.005083	4.926	72	<0.05	Affected by non-detect values
	BOD	0.167	5.059	47	<0.05	Affected by non-detect values
	Total Org. Carbon	-0.07276	-0.3675	26	NS	
	Conductivity	1.374	0.6418	61	NS	Break in data record
	Temperature	-0.05002	-0.4429	72	NS	
	pH	-0.02034	-1.801	72	<0.1	
	Faecal Coliforms	72.42	1.694	72	<0.1	
	Diss. Ox (% sat)	-0.02034	-1.801	72	<0.1	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB21	Turbidity	0.3104	1.31	72	<0.1	
	Visual Clarity	-0.005121	-0.1964	71	NS	
	Total N	-0.3386	-1.369	26	<0.2	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Total P	0.04413	3.195	26	<0.05	
	Diss. Reactive P	0.007242	5.061	72	<0.05	
	Nitrate N	-0.02562	-0.8915	72	NS	
	Ammoniacal N	0	0.2581	72	NS	
	BOD	0.101	1.414	47	<0.2	
	Total Org. Carbon	0.3302	0.367	26	NS	
	Conductivity	-3.555	-1.603	61	<0.2	Break in data record
	Temperature	0.01278	0.1156	72	NS	
	pH	-0.0323	-2.439	71	<0.05	
	Faecal Coliforms	223.7	2.253	72	<0.05	
	Diss. Ox (% sat)	-0.1015	-0.5387	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB22	Turbidity	-0.01652	-0.4657	52	NS	Break in data record
	Visual Clarity	0.08072	0.4425	72	NS	
	Total N	0.01005	0.4637	26	NS	
	Total P	0	0	26	NS	
	Diss. Reactive P	0	0.7056	72	NS	
	Nitrate N	-0.004969	-1.317	72	<0.2	
	Ammoniacal N	0	0	72	NS	
	BOD	0	0.2981	47	NS	
	Total Org. Carbon	0.04573	0	26	NS	
	Conductivity	1	1.931	61	<0.1	Break in data record
	Temperature	-0.2927	-2.099	72	<0.05	
	pH	0	-1.662	72	<0.1	
	Faecal Coliforms	2.172	0.9313	41	NS	
	Diss. Ox (% sat)	-0.1183	-0.1924	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB22	Turbidity	-0.04477	-1.751	51	<0.1	Break in data record
Flow-adjusted	Visual Clarity	0.187	1.885	71	<0.1	
	Total N	0.01005	0.4637	26	NS	
	Total P	-0.0009607	-0.2399	26	NS	
	Diss. Reactive P	-5.84E-06	-0.8245	71	NS	
	Nitrate N	-0.004117	-1.296	71	<0.2	
	Ammoniacal N	0	0.0771	71	NS	
	BOD	0.004203	2.217	46	<0.05	
	Total Org. Carbon	0.1427	0.4564	26	NS	
	Conductivity	0.5997	1.998	60	<0.05	Break in data record
	Temperature	-0.2273	-1.492	71	<0.2	
	pH	-0.01744	-2.002	71	<0.05	
	Faecal Coliforms	-0.2152	-0.0883	41	NS	
	Diss. Ox (% sat)	-0.08899	-0.2356	71	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB23	Turbidity	0.02461	0.7338	72	NS	
	Visual Clarity	-0.1796	-1.75	72	<0.1	
	Total N	-0.03659	-0.4564	26	NS	
	Total P	-0.002734	-1.621	26	0.2	
	Diss. Reactive P	0	2.821	72	<0.05	Affected by non-detect values
	Nitrate N	-0.007616	-1.178	72	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Ammoniacal N	0.005982	6.742	72	<0.05	Affected by non-detect values
	BOD	0.165	5.374	47	<0.05	Affected by non-detect values
	Total Org. Carbon	-0.1288	-0.09227	26	NS	
	Conductivity	1.046	2.026	61	<0.05	Break in data record
	Temperature	-0.1662	-1.348	72	<0.2	
	pH	0	-0.5119	72	NS	
	Faecal Coliforms	12.32	2.33	72	<0.05	
	Diss. Ox (% sat)	0.4656	1.097	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB24	Turbidity	0	0.3478	72	NS	
	Visual Clarity	-0.02302	-0.4234	72	NS	
	Total N	-0.008574	0	26	NS	
	Total P	-0.00159	-0.8409	26	NS	
	Diss. Reactive P	0	5.748	71	<0.05	Affected by non-detect values
	Nitrate N	-0.01495	-1.715	72	<0.1	
	Ammoniacal N	0.005966	7.07	72	<0.05	Affected by non-detect values
	BOD	0.1614	4.42	47	<0.05	Affected by non-detect values
	Total Org. Carbon	-0.1586	-0.4587	26	NS	
	Conductivity	0.4928	0.8413	61	NS	Break in data record
	Temperature	0.04176	0.3662	72	NS	
	pH	-0.008556	-0.8775	72	NS	
	Faecal Coliforms	5.586	0.5005	72	NS	
	Diss. Ox (% sat)	-0.09536	-0.07697	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB24	Turbidity	-0.0004406	0	72	NS	
Flow-adjusted	Visual Clarity	0.03133	0.4039	72	NS	
	Total N	-0.01367	-0.2739	26	NS	
	Total P	-0.00322	-0.8216	26	NS	
	Diss. Reactive P	-6.57E-06	-1.216	71	NS	
	Nitrate N	-0.01418	-1.635	72	<0.2	
	Ammoniacal N	0	0.5358	72	NS	
	BOD	0	1.28	47	NS	
	Total Org. Carbon	0.00398	-0.4564	26	NS	
	Conductivity	-0.06355	0.1971	61	NS	Break in data record
	Temperature	-0.2426	0.8656	72	NS	
	pH	-0.005103	-0.2501	72	NS	
	Faecal Coliforms	2.677	0.5194	72	NS	
	Diss. Ox (% sat)	0.008619	0	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB25	Turbidity	0.0262	0.4244	72	NS	
	Visual Clarity	0.01696	0.05771	72	NS	
	Total N	-0.02669	-0.5508	26	NS	
	Total P	-0.003666	-1.019	26	NS	
	Diss. Reactive P	0	6.121	72	<0.05	Affected by non-detect values
	Nitrate N	0	-0.1157	72	NS	
	Ammoniacal N	0.005966	7.07	72	<0.05	Affected by non-detect values
	BOD	0.1652	4.301	47	<0.05	Affected by non-detect values
	Total Org. Carbon	0.4181	1.193	26	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Conductivity	1.189	1.732	61	<0.1	Break in data record
	Temperature	-0.07554	-0.2888	72	NS	
	pH	0	-1.079	72	NS	
	Faecal Coliforms	4.396	0.6548	72	NS	
	Diss. Ox (% sat)	-0.4272	-0.7503	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB26	Turbidity	-0.05322	-2.341	70	<0.05	
	Visual Clarity	0.06324	0.5666	71	NS	
	Total N	-0.06822	-1.355	24	<0.2	
	Total P	-0.00344	-2.337	24	<0.05	
	Diss. Reactive P	0	5.255	71	<0.05	Affected by non-detect values
	Nitrate N	-0.01004	-1.176	71	NS	
	Ammoniacal N	0.006008	7.028	71	<0.05	Affected by non-detect values
	BOD	0.1661	5.384	47	<0.05	Affected by non-detect values
	Total Org. Carbon	0.05013	0.21	24	NS	
	Conductivity	1.564	3.493	60	<0.05	Break in data record
	Temperature	0.1004	0.6259	71	NS	
	pH	-0.02043	-1.803	71	<0.1	
	Faecal Coliforms	-4.692	-0.9778	71	NS	
	Diss. Ox (% sat)	0.2405	0.626	71	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB27	Turbidity	0.09983	1.278	71	NS	
	Visual Clarity	0.03035	0.7695	72	NS	
	Total N	-0.01037	-0.4974	25	NS	
	Total P	-0.004095	-0.9955	25	NS	
	Diss. Reactive P	0	-1.786	72	<0.1	Affected by non-detect values
	Nitrate N	-0.01995	-3.073	72	<0.05	
	Ammoniacal N	0	-0.2303	72	NS	Mostly non-detect values
	BOD	0	1.478	47	<0.2	Affected by non-detect values
	Total Org. Carbon	0	0	25	NS	
	Conductivity	1.01	2.855	61	<0.05	Break in data record
	Temperature	-0.09954	-0.6158	72	NS	
	pH	0	0.3166	72	NS	
	Faecal Coliforms	0	0	72	NS	
	Diss. Ox (% sat)	0.7495	2.137	72	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB28	Turbidity	0	0.0984	71	NS	
	Visual Clarity	-0.005904	-0.07699	72	NS	
	Total N	-0.2692	-2.389	25	<0.05	
	Total P	-0.03509	-1.897	25	<0.1	
	Diss. Reactive P	0	0.6031	72	NS	
	Nitrate N	0	-0.03856	72	NS	
	Ammoniacal N	0.01062	2.038	72	<0.05	
	BOD	0	0.9553	47	NS	Affected by non-detect values
	Total Org. Carbon	-0.1992	0.5991	25	NS	
	Conductivity	1.419	2.625	61	<0.05	Break in data record
	Temperature	0	0.03852	72	NS	
	pH	0	0.4992	72	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Faecal Coliforms	42.89	1.908	72	<0.1	
	Diss. Ox (% sat)	0.5612	1.102	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB28	Turbidity	-0.0153	-0.02079	68	NS	
Flow-adjusted data	Visual Clarity	-0.005917	-0.2847	69	NS	
	Total N	-0.2837	-2.182	25	<0.05	
	Total P	-0.04756	-1.587	25	<0.2	
	Diss. Reactive P	0.001506	0.6915	69	NS	
	Nitrate N	-0.005052	-0.4474	69	NS	
	Ammoniacal N	0.01006	1.973	69	<0.05	
	BOD	-0.0003916	-0.2788	44	NS	
	Total Org. Carbon	-0.081914	0	25	NS	
	Conductivity	1.061	2.988	58	<0.05	Break in data record
	Temperature	0.03108	0.2034	69	NS	
	pH	-0.003492	-0.2441	69	NS	
	Faecal Coliforms	40.3	1.505	69	<0.2	
	Diss. Ox (% sat)	0.5302	1.12	69	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB29	Turbidity	0.151	1.446	71	<0.2	
	Visual Clarity	0.009634	0.3179	24	NS	
	Total N	-0.0004314	-1.026	24	NS	
	Total P	0.001201	7.028	71	<0.05	Affected by non-detect values
	Diss. Reactive P	-0.002572	-1.308	71	<0.2	
	Nitrate N	0	0	71	NS	
	Ammoniacal N	0.1661	5.384	47	<0.05	Affected by non-detect values
	BOD	0.04621	0	24	NS	
	Total Org. Carbon	1.407	2.24	60	<0.05	Break in data record
	Conductivity	-0.01622	-0.05868	71	NS	
	Temperature	0	-0.6988	71	NS	
	pH	-5.21	-1.251	71	NS	
	Faecal Coliforms	0.1063	0.5298	69	NS	
	Diss. Ox (% sat)					
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB29	Turbidity	-0.01397	-1.037	70	NS	
Flow-adjusted	Visual Clarity	0.07754	0.8011	71	NS	
	Total N	0.005342	0.5194	24	NS	
	Total P	-0.001405	-1.143	24	NS	
	Diss. Reactive P	0	-1.023	71	NS	
	Nitrate N	-0.001692	-0.6839	71	NS	
	Ammoniacal N	-0.006585	-5.999	71	<0.05	Affected by non-detect values
	BOD	-0.001838	-1.378	47	<0.2	
	Total Org. Carbon	0.2239	0.7272	24	NS	
	Conductivity	0.5384	1.778	60	<0.1	Break in data record
	Temperature	-0.09636	-0.4103	71	NS	
	pH	-0.01288	-1.27	71	NS	
	Faecal Coliforms	-3.887	-0.9183	71	NS	
	Diss. Ox (% sat)	0.1023	0.4278	69	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
FB30	Turbidity	-0.1478	-0.6745	72	NS	
	Visual Clarity	0.01398	0.5699	71	NS	
	Total N	0.05323	0.2739	26	NS	
	Total P	0.002941	0.2739	26	NS	
	Diss. Reactive P	0	1.558	68	<0.2	
	Nitrate N	-0.02106	-1.061	70	NS	
	Ammoniacal N	-0.004938	-2.025	72	<0.05	
	BOD	0.06864	0.7473	47	NS	
	Total Org. Carbon	0.2095	0.2905	26	NS	
	Conductivity	8.38	1.556	61	<0.2	Break in data record
	Temperature	0	0.03856	72	NS	
	pH	0	0.4819	72	NS	
	Faecal Coliforms	-104.8	-1.52	72	<0.2	
	Diss. Ox (% sat)	2.429	1.135	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB30	Turbidity	-0.2623	-1.122	60	NS	
Flow-adjusted	Visual Clarity	0.02162	0.6576	59	NS	
	Total N	0.0474	0.4564	26	NS	
	Total P	-0.0002721	-0.0927	26	NS	
	Diss. Reactive P	0.0003011	1.884	56	<0.1	
	Nitrate N	-0.001693	-0.07722	58	NS	
	Ammoniacal N	-0.00498	-1.865	60	<0.1	
	BOD	-0.1716	-2.028	33	<0.05	
	Total Org. Carbon	0.2868	0.8216	26	NS	
	Conductivity	-11.91	0.3018	49	NS	Break in data record
	Temperature	0.03749	0.3241	60	NS	
	pH	0.004502	0.4238	60	NS	
	Faecal Coliforms	-51.26	-1.022	60	NS	
	Diss. Ox (% sat)	2.931	1.77	60	<0.1	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB31	Turbidity	-0.08464	-1.952	41	<0.1	
	Visual Clarity	0.08456	0.8468	72	NS	
	Total N	0.0204	1.473	26	<0.2	
	Total P	-0.00392	-1.285	26	<0.2	
	Diss. Reactive P	0	-1.593	72	<0.2	
	Nitrate N	-0.005267	-0.9855	41	NS	
	Ammoniacal N	0	0	72	NS	All non-detect values
	BOD	0	0	47	NS	All non-detect values
	Total Org. Carbon	0.09789	0.09152	26	NS	
	Conductivity	1.433	3.451	61	<0.05	Break in data record
	Temperature	-0.2344	-0.8872	41	NS	
	pH	0	0.5558	41	NS	
	Faecal Coliforms	-1.753	-2.257	72	<0.05	Not environmentally significant
	Diss. Ox (% sat)	0.7599	3.524	72	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB31	Turbidity	-0.06986	-2.119	41	<0.05	
Flow-adjusted	Visual Clarity	0.05913	1.135	72	NS	
	Total N	0.02264	1.004	26	NS	

Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
	Total P	-0.004057	-1.369	26	<0.2	
	Diss. Reactive P	-3.303E-05	-1.558	72	<0.2	Affected by non-detect values
	Nitrate N	-0.004891	-0.9713	41	NS	
	Ammoniacal N	0	0	72	NS	All non-detect values
	BOD	0	-0.1037	47	NS	All non-detect values
	Total Org. Carbon	0.08289	0.2739	26	NS	
	Conductivity	1.007	3.745	61	<0.05	Break in data record
	Temperature	-0.2344	-0.8872	41	NS	
	pH	0.009103	0.6181	41	NS	
	Faecal Coliforms	-2.022	-2.289	72	<0.05	Not environmentally significant
	Diss. Ox (% sat)	0.8035	3.366	72	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB32	Turbidity	0.03962	0.4634	72	NS	
Wainui - L.W. Park	Visual Clarity	0.05626	0.4426	72	NS	
	Total N	-0.0411	-1.01	26	NS	
	Total P	-0.006225	-1.465	26	<0.2	
	Diss. Reactive P	0	2.215	72	<0.05	Due to 4 results > detection in 2003
	Nitrate N	-0.01256	-2.144	72	<0.05	
	Ammoniacal N	0	0.1952	72	NS	All non-detect values
	BOD	0	1.593	47	<0.2	All non-detect values
	Total Org. Carbon	0.04205	0	26	NS	
	Conductivity	0.4829	0.4941	61	NS	Break in data record
	Temperature	-0.1813	-1.406	72	<0.1	
	pH	1.66	3.522	72	<0.05	
	Faecal Coliforms	-27.25	-1.406	72	<0.1	
	Diss. Ox (% sat)	0	1.105	72	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB32	Turbidity	0.001426	0.04324	66	NS	
Flow-adjusted	Visual Clarity	0.04008	0.9512	66	NS	
	Total N	-0.03631	-0.7859	23	NS	
	Total P	-0.004402	-1.01	23	NS	
	Diss. Reactive P	1.314E-05	0.6053	66	NS	Mostly non-detect values
	Nitrate N	-0.01976	-3.675	66	<0.05	
	Ammoniacal N	-2.008E-06	-0.04324	66	NS	Mostly non-detect values
	BOD	0.0006964	0.8389	44	NS	
	Total Org. Carbon	0.01421	0	23	NS	
	Conductivity	0.4115	1.059	57	NS	Break in data record
	Temperature	-0.06687	-0.1729	66	NS	
	pH	0.01656	1.384	66	<0.2	
	Faecal Coliforms	-33.4	-1.513	66	<0.1	
	Diss. Ox (% sat)	1.951	3.891	66	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB33	Turbidity	0	0.3092	72	NS	
	Visual Clarity	0.09424	-1.578	72	<0.2	
	Total N	-0.2294	-2.381	26	<0.05	
	Total P	-0.02654	-2.569	26	<0.05	
	Diss. Reactive P	-0.04603	-5.048	72	<0.05	
	Nitrate N	-0.196	-5.198	72	<0.05	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Ammoniacal N	-0.02509	-5.836	72	<0.05	
	BOD	0	-0.8358	47	NS	
	Total Org. Carbon	-0.2474	-1.01	26	NS	
	Conductivity	-2.552	-1.655	61	<0.1	Break in data record
	Temperature	-0.2086	-1.232	72	NS	
	pH	0.04654	2.275	71	<0.05	
	Faecal Coliforms	-62.54	-2.291	72	<0.05	
	Diss. Ox (% sat)	2.894	4.619	72	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB33	Turbidity	0.003015	0.04324	66	NS	
Flow-adjusted	Visual Clarity	0.07818	1.384	66	<0.2	
	Total N	-0.1352	-1.46	23	<0.2	
	Total P	-0.01725	-2.133	23	<0.05	
	Diss. Reactive P	-0.05384	-6.615	66	<0.05	
	Nitrate N	-0.2155	-6.01	66	<0.05	
	Ammoniacal N	-0.02586	-5.534	66	<0.05	
	BOD	-0.05639	-1.079	44	NS	
	Total Org. Carbon	-0.01626	0	23	NS	
	Conductivity	-3.196	-3.99	57	<0.05	Break in data record
	Temperature	-0.01551	-0.04324	66	NS	
	pH	0.04546	2.486	65	<0.05	
	Faecal Coliforms	-60.48	-2.637	66	<0.05	
	Diss. Ox (% sat)	3.191	4.886	66	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB34	Turbidity	-0.1611	-1.663	70	<0.1	
	Visual Clarity	0.08807	1.7	70	<0.1	
	Total N	-0.2524	-1.734	26	<0.1	
	Total P	-0.02209	-1.369	26	<0.2	
	Diss. Reactive P	-0.01274	-4.877	70	<0.05	
	Nitrate N	-0.7473	-3.748	70	<0.05	
	Ammoniacal N	0	-2.681	70	<0.05	
	BOD	0	-2.523	45	<0.05	
	Total Org. Carbon	0	0	26	NS	
	Conductivity	-0.599	-0.4895	59	NS	Break in data record
	Temperature	-0.1004	-0.4402	70	NS	
	pH	0	-0.204	70	NS	
	Faecal Coliforms	-39.04	-2.547	70	<0.05	
	Diss. Ox (% sat)	0.6959	1.22	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB35	Turbidity	0	-0.05871	72	NS	
	Visual Clarity	0.1297	0.7312	72	NS	
	Total N	0.01806	1.732	26	<0.1	
	Total P	-0.003487	-1.448	26	<0.2	
	Diss. Reactive P	0.001202	7.07	72	<0.05	Affected by non-detect values
	Nitrate N	0	-0.9873	72	NS	
	Ammoniacal N	0.006012	6.784	72	<0.05	Affected by non-detect values
	BOD	0.1666	5.374	47	<0.05	Affected by non-detect values
	Total Org. Carbon	0.1028	0.3722	26	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Conductivity	2.949	2.474	61	0.05	Break in data record
	Temperature	0.07962	0.5006	72	NS	
	pH	0	-0.931	72	NS	
	Faecal Coliforms	-0.4966	-0.3277	72	NS	
	Diss. Ox (% sat)	0.8158	1.693	72	<0.1	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB36	Turbidity	0.03577	1.021	71	NS	
	Visual Clarity	-0.2148	-1.001	69	NS	
	Total N	-0.01355	-0.8058	25	NS	
	Total P	-0.001291	-0.4024	25	NS	
	Diss. Reactive P	-0.0002482	-2.282	71	<0.05	
	Nitrate N	0.001389	1.022	71	NS	
	Ammoniacal N	0	-1.908	71	<0.1	
	BOD	0	-0.6209	50	NS	
	Total Org. Carbon	-0.1796	-0.713	25	NS	
	Conductivity	0	0.06141	69	NS	
	Temperature	-0.101	-0.6294	71	NS	
	pH	0.007242	0.431	69	NS	
	Faecal Coliforms	0	-0.2681	69	NS	
	Diss. Ox (% sat)	-0.1003	-1.161	71	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB36	Turbidity	0.02758	0.6869	71	NS	
Flow adjusted	Visual Clarity	-0.09388	-1.389	69	<0.2	
	Total N	-0.01641	-0.7	25	NS	
	Total P	0.0008293	-0.7	25	NS	
	Diss. Reactive P	-0.0002519	-2.257	71	<0.05	
	Nitrate N	0.0008866	0.5692	71	NS	
	Ammoniacal N	-1.478E-05	-1.708	71	<0.1	
	BOD	-0.0004853	-0.5654	50	NS	
	Total Org. Carbon	-0.117	-0.5	25	NS	
	Conductivity	0.31	0.613	69	NS	
	Temperature	-0.06869	-0.8047	71	NS	
	pH	0.007377	0.4495	69	NS	
	Faecal Coliforms	-0.03144	-0.2043	69	NS	
	Diss. Ox (% sat)	-0.09866	-1.119	71	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB37	Turbidity	0.03654	0.7687	72	NS	
	Visual Clarity	-0.1048	-0.9994	71	NS	
	Total N	-0.006535	-0.6022	25	NS	
	Total P	-0.0004418	-0.3059	25	NS	
	Diss. Reactive P	0	0.438	72	NS	
	Nitrate N	0.001665	0.4614	72	NS	
	Ammoniacal N	0	0.2907	72	NS	
	BOD	0	1.649	51	<0.1	
	Total Org. Carbon	0.04573	0.2026	25	NS	
	Conductivity	1.036	1.123	70	NS	
	Temperature					Data not readily available for analysis
	pH	0	-0.06038	70	NS	

Site No.	Variable	Slope	Z	n	p	Comments
	Faecal Coliforms	0	0.03918	71	NS	
	Diss. Ox (% sat)	0	0.2554	71	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB38	Turbidity	0.1281	1.276	71	NS	
	Visual Clarity	-0.0876	-1.1	71	NS	
	Total N	-0.003259	0	25	0	
	Total P	-0.005577	-1.9	25	<0.1	
	Diss. Reactive P	-0.0003267	-1.306	71	<0.2	
	Nitrate N	0.01262	1.61	71	<0.2	
	Ammoniacal N	0	1.634	71	<0.2	
	BOD	0	1.083	50	NS	
	Total Org. Carbon	0.6422	1.523	25	<0.2	
	Conductivity	1.014	0.4295	69	NS	
	Temperature	-0.2177	-1.102	70	NS	
	pH	0	0	69	NS	
	Faecal Coliforms	-1.127	0.2356	71	NS	
	Diss. Ox (% sat)	0.09329	0.5501	71	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB39	Turbidity	0.09902	1.278	71	NS	
	Visual Clarity	-0.05422	-0.9426	71	NS	
	Total N	-0.004625	-0.1	25	NS	
	Total P	0.009109	1.204	25	NS	
	Diss. Reactive P	0	0.1183	71	NS	
	Nitrate N	0.004521	0.4907	71	NS	
	Ammoniacal N	0	0.5005	71	NS	
	BOD	0.02139	1.25	50	NS	
	Total Org. Carbon	-0.4836	-1.304	25	<0.2	
	Conductivity	0.3318	0.1227	69	NS	
	Temperature	-0.1308	-0.7869	71	NS	
	pH	0.01462	0.6773	69	NS	
	Faecal Coliforms	-0.8512	-0.8436	70	NS	
	Diss. Ox (% sat)	0.2309	0.7463	71	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB40	Turbidity	0.08855	0.7692	72	NS	
	Visual Clarity	-0.05201	-1.441	72	<0.1	
	Total N	-0.1678	-1.305	25	<0.1	
	Total P	-0.005165	-1.003	25	NS	
	Diss. Reactive P	0	-0.05798	72	NS	
	Nitrate N	0.006322	0.3457	72	NS	
	Ammoniacal N	0	-0.53	72	NS	
	BOD	0.009837	0.3567	51	NS	
	Total Org. Carbon	-0.109	-0.425	24	NS	
	Conductivity	2.815	1.843	70	<0.1	
	Temperature					Data not readily available for analysis
	pH	0.009658	0.6436	70	NS	
	Faecal Coliforms	-2.302	-0.7766	70	NS	
	Diss. Ox (% sat)	-0.1435	-0.5595	70	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
FB40	Turbidity	-0.01326	-0.1536	72	NS	
Flow adjusted	Visual Clarity	-0.0376	-1.421	72	<0.2	
	Total N	-0.1095	-1.1	25	NS	
	Total P	-0.003106	-0.7	25	NS	
	Diss. Reactive P	0.000219	0.5378	72	NS	
	Nitrate N	0.005084	0.3073	72	NS	
	Ammoniacal N	-0.0002227	-0.7298	72	NS	
	BOD	0.00742	0.3883	51	NS	
	Total Org. Carbon	-0.008731	0	24	NS	
	Conductivity	2.516	1.841	70	<0.1	
	Temperature					Data not readily available for analysis
	pH	-0.004099	-0.2801	70	NS	
	Faecal Coliforms	-2.195	-0.8147	70	NS	
	Diss. Ox (% sat)	-0.1684	-0.5588	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB41	Turbidity	0.1043	1.546	70	<0.2	
	Visual Clarity	-0.08483	-2.065	69	<0.05	
	Total N	-0.01825	0	24	NS	
	Total P	-0.0183	-2.21	24	<0.05	
	Diss. Reactive P	0.00123	2.416	70	<0.05	
	Nitrate N	0.008607	0.3207	70	NS	
	Ammoniacal N	0.0006862	1.148	70	NS	
	BOD	0.1045	1.899	50	<0.1	
	Total Org. Carbon	0.2979	0.8414	24	NS	
	Conductivity	-1.555	-0.3766	68	NS	
	Temperature	-0.1469	-1.189	69	NS	
	pH	0	0.2109	68	NS	
	Faecal Coliforms	5.741	0.4086	69	NS	
	Diss. Ox (% sat)	0.04614	0.1203	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB42	Turbidity	-0.0991	-0.4029	55	NS	
	Visual Clarity	-0.03309	-0.5456	55	NS	
	Total N	-0.1296	-1.5	25	<0.2	
	Total P	0.006026	0.1	25	NS	
	Diss. Reactive P	-0.0004966	-8068	55	NS	
	Nitrate N	0.002027	0.5458	55	NS	
	Ammoniacal N	-0.002061	-2.194	55	<0.05	
	BOD	0.05161	0.4807	34	NS	
	Total Org. Carbon	0.6537	1.483	24	<0.2	
	Conductivity	0	-0.06086	53	NS	
	Temperature					Data not readily available for analysis
	pH	0.074	2.963	53	<0.05	
	Faecal Coliforms	1.246	0.06351	51	NS	
	Diss. Ox (% sat)	1.457	1.418	53	<0.2	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB42	Turbidity	-0.125	-0.6022	55	NS	
Flow adjusted	Visual Clarity	-0.01817	-0.4302	55	NS	
	Total N	-0.1211	-1.3	25	<0.2	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Total P	-0.001671	-0.3	25	NS	
	Diss. Reactive P	-0.00044	-0.8316	55	NS	
	Nitrate N	0.005125	1.176	55	NS	
	Ammoniacal N	-0.001773	-2.151	55	<0.05	
	BOD	-0.04468	-0.1202	34	NS	
	Total Org. Carbon	0.2172	0.2097	24	NS	
	Conductivity	-0.8192	-0.3335	53	NS	
	Temperature					Data not readily available for analysis
	pH	0.005875	3.183	53	0.05	
	Faecal Coliforms	3.409	0.3084	51	NS	
	Diss. Ox (% sat)	1.156	1.478	53	<0.2	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB43	Turbidity	-0.2745	-1.948	71	<0.1	
	Visual Clarity	0.05982	1.747	71	<0.1	
	Total N	0.06988	0.1	25	NS	
	Total P	0.01912	-1.0404	25	<0.2	
	Diss. Reactive P	-0.0003358	-0.3933	71	NS	
	Nitrate N	0.05712	1.021	71	NS	
	Ammoniacal N	-0.001003	-1.367	71	<0.2	
	BOD	-0.04033	-0.3992	50	NS	
	Total Org. Carbon	0	0	24	NS	
	Conductivity	0.4698	0.1841	69	NS	
	Temperature	-0.1895	-1.119	71	NS	
	pH	-15.99	-1.92	70	<0.1	
	Faecal Coliforms	0	0.2256	69	NS	
	Diss. Ox (% sat)	-0.2897	-0.1603	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB44	Turbidity	-0.03025	-1.416	71	<0.2	
	Visual Clarity	0.06037	0.942	70	NS	
	Total N	0.2373	13	25	<0.2	
	Total P	-0.001851	-1.515	25	<0.2	
	Diss. Reactive P	-0.003285	-1.592	71	<0.2	
	Nitrate N	-0.03339	-0.8439	71	NS	
	Ammoniacal N	0	1.33	71	<0.2	
	BOD	0	1.161	50	NS	
	Total Org. Carbon	-0.4968	-2.135	24	<0.05	
	Conductivity	-0.6727	-0.8002	69	NS	
	Temperature	-0.1422	-0.6878	71	NS	
	pH	0.03358	1.621	69	<0.2	
	Faecal Coliforms	-5.632	-2.465	70	<0.05	
	Diss. Ox (% sat)	0.3038	0.9225	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB45	Turbidity	0.07895	1.217	71	NS	
	Visual Clarity	-0.2078	-1.727	71	<0.1	
	Total N	-0.01933	-0.7	25	NS	
	Total P	-0.001094	-0.4054	25	NS	
	Diss. Reactive P	-0.0003194	-2.581	71	<0.05	
	Nitrate N	-0.00306	-0.8837	71	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Ammoniacal N	0	3.953	71	<0.05	Affected by non-detect values?
	BOD	0	0.9951	50	NS	
	Total Org. Carbon	-0.09311	-0.7116	25	NS	
	Conductivity	0.4917	0.9837	69	NS	
	Temperature	-0.143	-0.766	71	NS	
	pH	0.007555	0.7636	69	NS	
	Faecal Coliforms	0.7274	1.382	71	<0.2	
	Diss. Ox (% sat)	-0.03478	-0.3737	71	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB46	Turbidity	0.03791	0.2554	71	NS	
	Visual Clarity	0.01004	0.1221	69	NS	
	Total N	-0.0004088	0	25	NS	
	Total P	-0.00628	-0.5015	25	NS	
	Diss. Reactive P	0.001038	1.654	71	<0.1	
	Nitrate N	-0.04305	-1.924	71	<0.1	
	Ammoniacal N	-0.002007	-1.988	71	<0.05	
	BOD	0.0561	0.9321	50	NS	
	Total Org. Carbon	-0.6238	-0.5015	25	NS	
	Conductivity	-1.83	-0.6954	69	NS	
	Temperature	-0.1262	0.8643	71	NS	
	pH	0.01931	0.9645	69	NS	
	Faecal Coliforms	-5.714	-1.041	71	NS	
	Diss. Ox (% sat)	0.9658	0.862	70	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB47	Turbidity	-0.007585	-0.4523	71	NS	
	Visual Clarity	-0.005678	0	70	NS	
	Total N	-0.02333	-0.9027	25	NS	
	Total P	-0.0009656	-1.146	25	NS	
	Diss. Reactive P	-0.0004865	-3.668	71	<0.05	
	Nitrate N	0.0005145	0.3734	71	NS	
	Ammoniacal N	0	3.395	71	<0.05	Affected by non-detect values?
	BOD	-0.01858	-1.782	50	<0.1	
	Total Org. Carbon	-0.1048	-0.8153	25	NS	
	Conductivity	0.6559	1.026	69	NS	
	Temperature	-0.05088	-0.7675	71	NS	
	pH	0	-0.1031	69	NS	
	Faecal Coliforms	0	0.06016	71	NS	
	Diss. Ox (% sat)	0.1392	1.064	69	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB47	Turbidity	0.001899	0.01963	71	NS	
Flow Adjusted	Visual Clarity	-0.03786	-0.3398	70	NS	
	Total N	-0.008428	-0.7	25	NS	
	Total P	0.0004838	0.5	25	NS	
	Diss. Reactive P	-0.0004165	-3.238	71	<0.05	
	Nitrate N	3.267E-05	0.01963	71	NS	
	Ammoniacal N	1.351E-05	2.493	71	<0.05	
	BOD	-0.0183	-1.962	50	<0.05	
	Total Org. Carbon	-0.1183	-0.4193	24	NS	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Conductivity	0.2566	1.103	69	NS	
	Temperature	-0.1747	-1.315	71	<0.2	
	pH	-0.008296	-0.6947	69	NS	
	Faecal Coliforms	0.008076	0.05888	71	NS	
	Diss. Ox (% sat)	0.1424	1.164	69	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB48	Turbidity	-0.03503	-0.7683	71	NS	
	Visual Clarity	-0.02474	-0.3338	71	NS	
	Total N	-0.1534	-1.304	25	<0.2	
	Total P	0.002324	0.7025	25	NS	
	Diss. Reactive P	0.000323	0.6908	71	NS	
	Nitrate N	0.01109	0.8441	71	NS	
	Ammoniacal N	-0.0002519	-1.743	71	<0.1	
	BOD	-0.01003	0.9105	50	NS	
	Total Org. Carbon	0	-0.5455	24	NS	
	Conductivity	0.7373	0.8812	69	NS	
	Temperature	-0.006559	-0.6888	71	NS	
	pH	0.006727	0.9929	69	NS	
	Faecal Coliforms	-3.683	-1.593	71	<0.2	
	Diss. Ox (% sat)	0.1424	0.368	69	NS	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB49	Turbidity	-0.1006	-2.441	71	<0.05	
	Visual Clarity	0.05371	0.9818	71	NS	
	Total N	0.1182	0.5018	25	NS	
	Total P	0.03842	1.7	25	<0.1	
	Diss. Reactive P	0.03838	1.493	71	<0.2	
	Nitrate N	0.04979	1.296	71	<0.2	
	Ammoniacal N	0.000958	0.3732	71	NS	
	BOD	0.05456	0.6655	50	NS	
	Total Org. Carbon	-0.09287	-0.5083	25	NS	
	Conductivity	1.241	1.148	69	NS	
	Temperature	-0.08663	-0.7084	71	NS	
	pH	0.0171	1.958	69	<0.1	
	Faecal Coliforms	-14.05	-1.08	71	NS	
	Diss. Ox (% sat)	0.947	2.085	69	<0.05	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB50	Turbidity	0.006247	0.5115	71	NS	
	Visual Clarity	-0.05325	-0.5692	71	NS	
	Total N	-0.2129	-1.9	25	<0.1	
	Total P	-0.009037	-1.007	25	NS	
	Diss. Reactive P	0.0002484	0.9547	71	NS	
	Nitrate N	0.002549	0.7073	71	NS	
	Ammoniacal N	0	-0.7488	71	NS	
	BOD	-0.02999	-1.2	50	NS	
	Total Org. Carbon	0.2542	1.031	25	NS	
	Conductivity	-3.349	-0.9822	69	NS	
	Temperature	-0.3079	-2.182	71	<0.05	
	pH	-0.03476	-2.811	69	<0.05	

Site No.	Variable	Slope	Z	n	*p*	Comments
	Faecal Coliforms	-5.654	-1.985	71	<0.05	
	Diss. Ox (% sat)	-0.8665	-1.33	69	<0.2	
Site No.	**Variable**	**Slope**	**Z**	**n**	***p***	**Comments**
FB51	Turbidity	-0.04741	-1.495	71	<0.2	
	Visual Clarity	-0.02507	-0.02507	71	NS	
	Total N	-0.01632	-1.1	25	NS	
	Total P	0.0009766	0.4051	25	NS	
	Diss. Reactive P	0	-1.475	71	<0.2	
	Nitrate N	-0.001999	-1.022	71	NS	
	Ammoniacal N	0	3.312	71	<0.05	Affected by non-detect values
	BOD	-0.01018	0.8725	50	NS	
	Total Org. Carbon	-0.3008	-0.9561	24	NS	
	Conductivity	0.3321	0.6364	69	NS	
	Temperature	-0.252	-1.844	70	<0.1	
	pH	0	-0.4336	69	NS	
	Faecal Coliforms	0	0.03941	71	NS	
	Diss. Ox (% sat)	0.2086	0.7041	67	NS	